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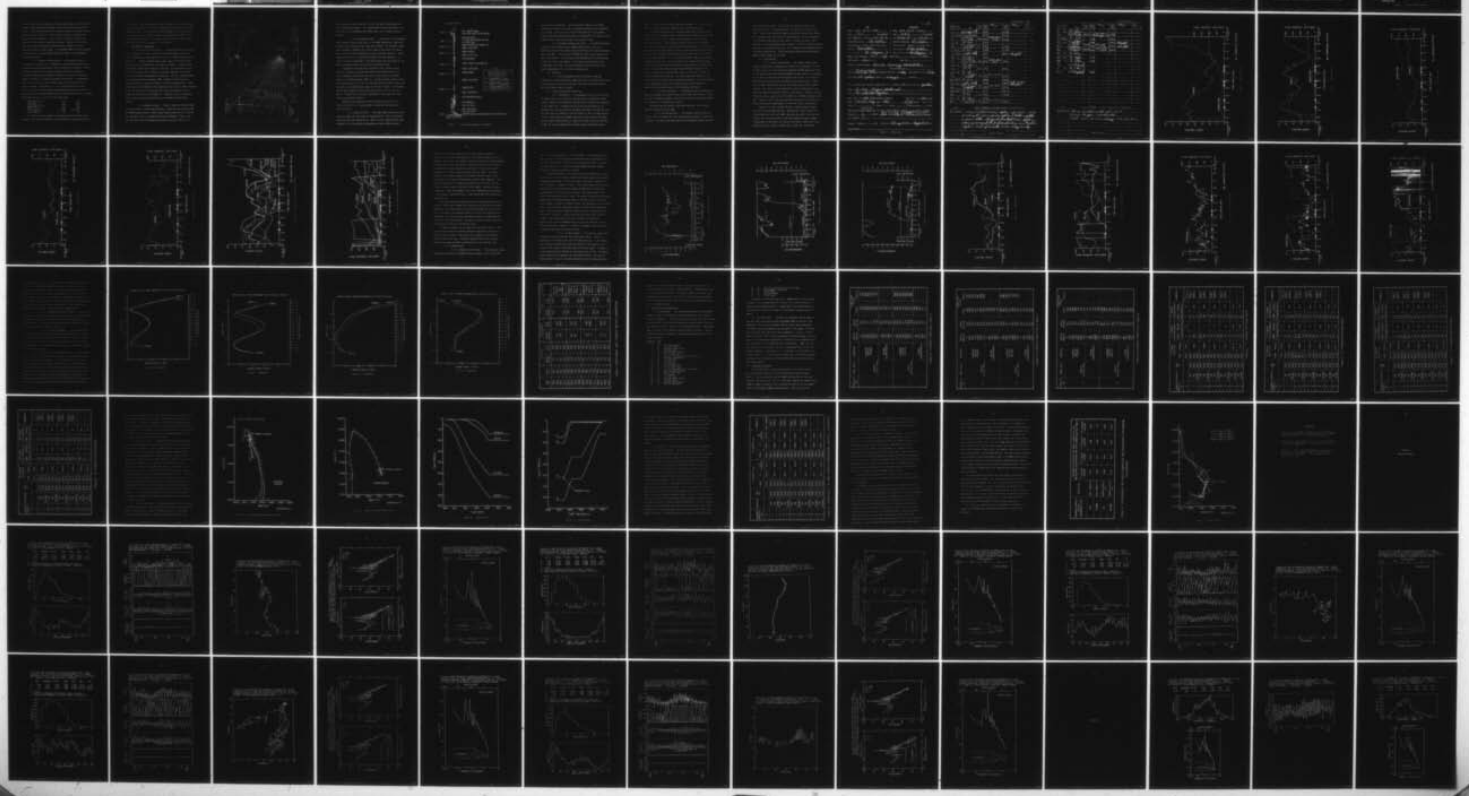

WHOI-77-53

Woods Hole Oceanographic Institution

VALIDATION TESTING OF THE DOCMS INTERMEDIATE MOORING

by

Robert G. Walden
Clayton W. Collins, Jr.
Peter R. Clay
Patrick O'Malley

September 1977

TECHNICAL REPORT

Prepared for the Office of Naval Research under Contracts N00014-75-C-1064; NR 294-044; N00014-76-C-0197; NR 083-400 and the Naval Facilities Engineering Command under Contract N62477-76-C-0048.

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A Deep Ocean Current Measurement System (DOCMS) was developed for the U.S. Naval Oceanographic Office under a contract with the U.S. Naval Facilities Engineering Command. A test of this mooring was made at the Pacific Missile Range Barking Sands Facility, Hawaii, to validate the design predictions. The motions of the mooring, both predicted and measured are tabulated and show good agreement. Current measurements were made from current meters on the DOCMS and on a nearby intermediate mooring. Current measurements from the surface to 500 meters were also obtained using an acoustic dropsonde. (Cont. on back)

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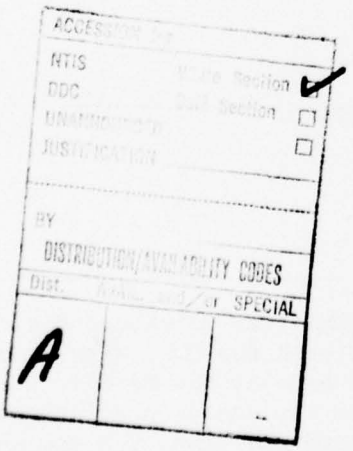
Acoustic pingers on the mooring were tracked in X, Y and Z coordinates by the range to provide data on the mooring motions and shape.



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Woods Hole, Massachusetts 02543

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Approved for Distribution Earl E Hays

Earl E. Hays, Chairman
Department of Ocean Engineering

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ABSTRACT

A Deep Ocean Current Measurement System (DOCMS) was developed for the U. S. Naval Oceanographic Office under a contract with the U. S. Naval Facilities Engineering Command. A test of this mooring was made at the Pacific Missile Range Barking Sands Facility, Hawaii, to validate the design predictions. The motions of the mooring, both predicted and measured are tabulated and show good agreement. Current measurements were made from current meters on the DOCMS and on a nearby intermediate mooring. Current measurements from the surface to 500 meters were also obtained using an acoustic dropsonde. Acoustic pingers on the mooring were tracked in X, Y and Z coordinates by the range to provide data on the mooring motions and shape.

Acknowledgements

The authors wish to acknowledge the support of the Naval Facilities Engineering Command, Office of Naval Research Code 485, NOAA Data Buoy Office and the Naval Oceanographic Office which made the validation experiment possible. The Pacific Missile Range at Pt. Mugu, California and their facility at Barking Sands, Kauai provided excellent services and acoustic tracking data. The Military Sealift Command through the Naval Oceanographic Office provided an excellent vessel for the test.

The VACM data summaries (Appendix 2) were provided by David Halpern and Hugh Milburn of the Pacific Marine Environmental Laboratory, NOAA, Seattle, Washington. The data from the Niskin current meter was supplied by Leslie Bonde, EG&G Washington Analytical Services Center, Inc., Rockville, Maryland. Mr. Richard Noble of the Naval Underwater Systems Center, Newport, Rhode Island, provided the Aanderaa current meter data. William Vachon of the C. S. Draper Laboratories, Cambridge, Massachusetts supplied the temperature/pressure data.

We express our gratitude to the Information Processing Center at the Institution for help in processing the large amount of data acquired during the experiment. The graphic work was done by Miss Nancy Barnes and Mrs. Frances Williams Dunlap.

We also gratefully acknowledge the services of Mrs. Charlotte Muzzey for manuscript typing.

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VALIDATION TESTING OF THE DOCMS INTERMEDIATE MOORING

Introduction

This report discusses an experiment which was staged at the Pacific Missile Range Facility, Barking Sands, Kauai, Hawaii, in which a typical DOCMS mooring, instrumented with current meters, acoustic pingers, and temperature/pressure recorders was installed. The design and computer modeling of the mooring is presented and the predicted response compared with the measured response.

1.0 DOCMS Mooring

1.1 Background - The Deep Ocean Current Measuring System (DOCMS) was developed for NAVFAC/NAVOCEANO to reliably measure deep ocean currents in support of ocean engineering and construction projects. The program to develop the system consisted of four phases. Phase I provided the necessary designs, specifications and technical guidance for procurement of the systems. Under Phase II the necessary (DOCMS) components were procured and assembled. Phase III defined instrumentation requirements, test processes and procedural methods necessary to validate the operation of the system. Task 4 under this phase was the actual validation operation

1.2 Phase III Task 4 Activities - The validation testing of the DOCMS took place in October 1976 at Barking Sands, Kauai. A mooring was designed and components assembled by the Woods Hole Oceanographic Institution and NAVOCEANO personnel. Woods Hole personnel were present aboard the vessel in order to provide help or instruction, if needed, to NAVOCEANO personnel during the mooring deployment and retrieval operations. The loads imposed upon the mooring during launch, while moored and during retrieval were representative of those to be expected in future operational DOCMS. Both environmental and mooring motion data were obtained during the experiment

interval. This data has been compiled in a form suitable to document the comparison of validation testing results against the design predictions.

1.3 Experimental Mooring Design - A typical DOCMS mooring was designed to be installed as an experimental mooring to compare its measured response against the response predicted by the computer design program NOYFB[1].

1.3.1 Current Profiles - In order to predict the motion of the DOCMS design, information was required on expected currents in the area of the experiment. Very little historical current data at the Barking Sands experiment site was available. Measurements of bottom currents were found, some showing unusually high currents. A sub-experiment was designed to obtain current profiles to approximately 900 meters depth by means of an acoustic dropsonde. This experiment was carried out about one year (September 1975) prior to the DOCMS test. The surface currents were generally less than 0.5 knots and around 0.2 kts at 900 meters. The general trend was towards the north. The measurements indicated no surprises such as 1-2 knot currents which had been reported. A conservative approach was taken for the mooring design by using a current profile of one knot from the top to the bottom.

1.3.2 Mooring Details - The mooring was designed for 1701 meters water depth. Figure 1 is a schematic representation of the mooring. A 44" aluminum sphere with 1050 pounds net buoyancy was used as the top flotation designed to be 253 meters below the surface. A strobe light and beacon radio were attached to the top of the sphere. Twenty meters of 3/8" chain was used to connect an Aanderaa current meter followed by an acoustic pinger, 63 meters of ¼" wire rope, 23 glass balls and another Aanderaa current meter at 366 meters. A precision temperature/pressure (T/P) recorder and another acoustic pinger were attached immediately below this current meter. Additional flotation consisting of six glass balls was

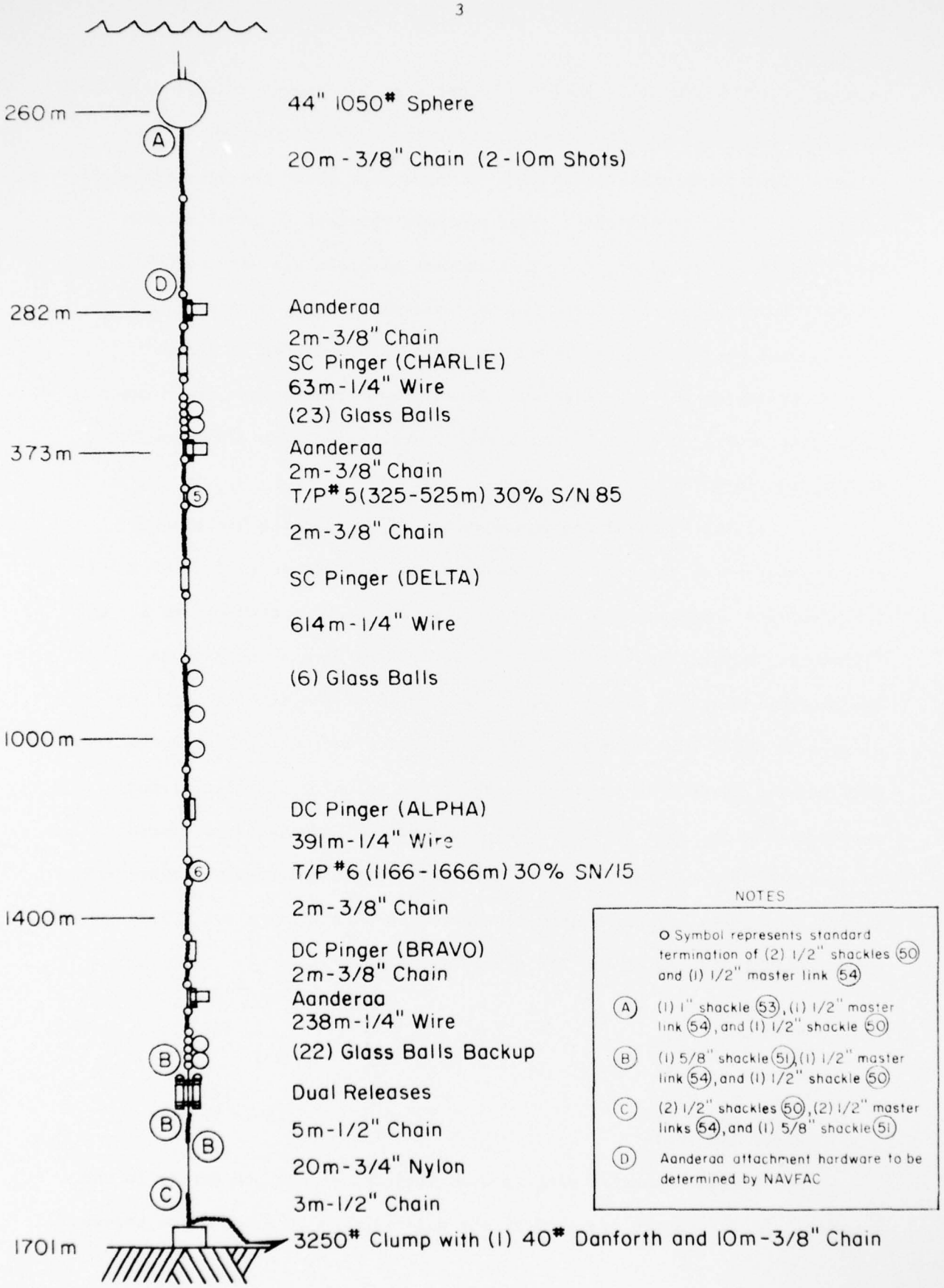


Figure 1 DOCMS Mooring #5 Schematic

located at 1000 meters followed by another acoustic pinger. A T/P recorder, acoustic pinger and another Aanderaa current meter were located at 1400 meters. Twenty-two glass balls were attached just above the acoustic anchor releases as back-up recovery[2]. Dual acoustic releases in parallel were used to provide redundancy. A short section of chain was used below the releases to prevent chafe during anchor descent. Twenty meters of nylon rope between this chain and the anchor provided compliance to reduce transients during the launch phase. A clump anchor made from chain embedded in concrete and a 40 pound Danforth anchor were used. The clump weighed 3250 pounds in water.

1.3.3 Special Instrumentation - The mooring had special instrumentation attached to it in addition to three Aanderaa current meters. Two precision temperature/pressure (T/P) recorders were attached at 376 and 1397 meters respectively to monitor pressure (depth) and temperature. The pressure measurement provided an indication of the precise depth and changes in depth due to mooring inclination from current. The temperature will be used to provide a more accurate sound velocity profile for the acoustic ranging. See Section 2.4.2.2 for further discussion of sound velocity. These recorders sampled both temperature and pressure every four minutes which was an accumulated average of 64 points taken every 3.75 seconds. Other characteristics of the T/P's are listed below.

Instrument Ser. No.	85	15
Depth (m)	376	1397
Temp. Range (°C)	0-20	0-20
Temperature LSB (°C)	.02	.02
Press. FS (m)	683	1703
Press. Range (m)	325-525	1167-1667
Press. LSB (cm)	20	50

Four special acoustic pingers were attached at various points in the mooring. These pingers operated at one pulse/second on frequencies between

13 and 37 kHz. They were mounted in special brackets to take the mooring load. Their position in X, Y and Z coordinates was monitored each second by ranging from three or more bottom mounted hydrophones. Position data has a least significant bit (LSB) of three ft and a nominal accuracy of 10 ft. The measurement accuracy of Z or distance off the bottom is less accurate near the bottom of the mooring due to the geometry.

2.0 The Validation Experiment

2.1 Site Selection and Facilities - An acoustic range was selected for the experiment in order to permit accurate measurements of mooring motion through acoustic and radar tracking. The U. S Naval Pacific Missile Range Facility (PMRF) at Barking Sands, Kauai, Hawaii was chosen because of the facilities available and its oceanic environment. Relatively high and variable currents were expected in the area. The experiment date was chosen for October 1976 to coincide with another experiment at the range which the Principal Investigator was conducting. The main experiment known as the Mooring Dynamics Experiment (MDE) consisted of acquiring motion and force data on a series of moorings of various configurations[3]. Validation testing of the DOCMS thus was a natural inclusion in the larger operation. A baseline current meter mooring provided current measurements at five depths two miles north of the DOCMS site. Personnel, vessel, instruments and the range facility were available for the DOCMS installation and recovery.

2.1.1 Bathymetric Survey - Figure 2 shows the acoustic range with the location of cables and hydrophones. Depth contours are also shown. The DOCMS location (Delta 5) and a current meter mooring (Delta 1) position are indicated. Prior to setting the mooring a bathymetric survey of the mooring location and the approach path starting six miles south of the

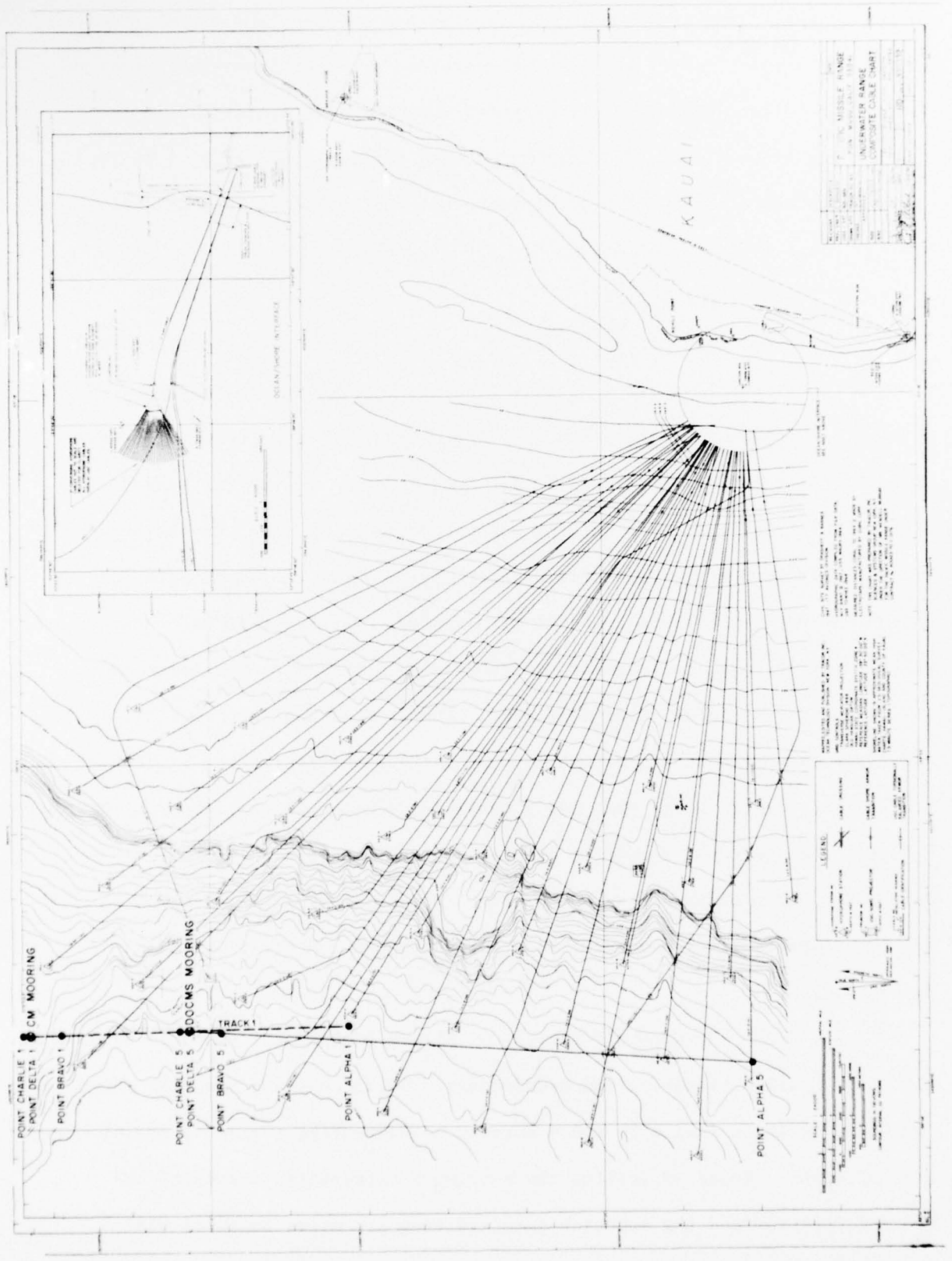


Figure 2 Acoustic Range

anchor drop point were conducted to correct the depth sounding gear and the indicated chart depths. The intended anchor position was chosen to be well clear of any hydrophones and cables and to be in terrain as flat as possible.

2.1.2 Site Environmental Data - In addition to the bathymetric data obtained from the vessel prior to the DOCMS installation, charts and historical data acquired by the range were obtained. All available reports were consulted to determine the current regime in the area of the experiment. Very little data throughout the water column was available. Bottom currents as swift as 1.5 knots were reported by a deep submersible. A series of acoustic dropsondes to 1000 meters depth which were made one year before indicated moderate currents with considerable shear.

To supplement this data and to provide a timely current forcing function to validate the predicted motions of the DOCMS mooring, five vector averaging current meters were set two miles north on a mooring similar to the DOCMS mooring (Figure 3). On this reference mooring current meters were placed at 200, 500, 750, 1000 and 1300 meters water depth, also two Niskin current meters were placed at 200 and 500 meters. On the DOCMS mooring three Aanderaa current meters were placed at 282, 373 and 1405 meters. In addition four acoustic dropsondes to 500 m depth were taken during the experiment duration.

Temperature was measured at each current meter and at the two T/P's (376 and 1397 m) to provide data to establish an accurate sound velocity profile.

2.1.3 Range Facilities - The range (PMRF) provided dock and logistics support for the vessel and transportation. They also furnished laboratory space and communications. When at sea the range provided radar tracking of the vessel during the bathymetric survey, anchor drop and

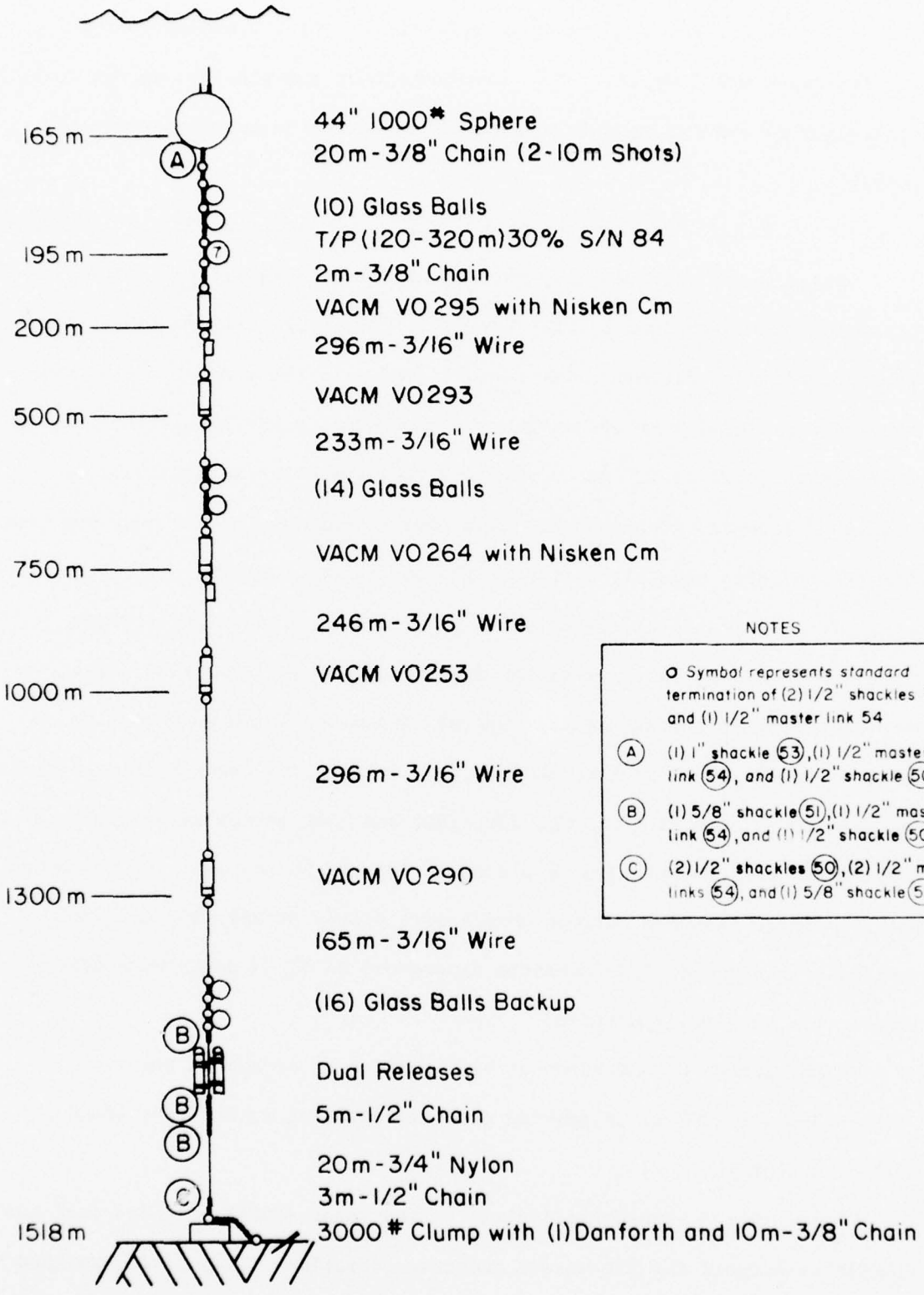


Figure 3 Current Meter Mooring #1 Schematic

mooring recovery operations. The four acoustic pingers on the DOCMS mooring were tracked in X, Y and Z coordinates during the whole experiment by the range. Each of the four acoustic dropsondes were also tracked. Computer and data processing facilities were furnished. The range delivered computer tapes, plots and listings of the acoustic tracks.

2.1.4 Deployment and Recovery Vessel - The USNS DE STEIGUER operated by the Military Sealift Command (MSC) Pacific, was used to deploy and retrieve the mooring, deploy and retrieve the acoustic dropsonde, and to take XBT's. The vessel is an AGOR type, 285 ft long, single screw with a bow thruster. The mooring was both launched and recovered through a large "U" frame on the fantail. The mooring line was stored on the intermediate winch drum. The vessel operated in and out of Port Allen, Kauai, approximately 25 miles from the mooring site.

2.2 Personnel

2.2.1 Naval Oceanographic Office personnel loaded and prepared the mooring aboard ship, rigged the vessel for launch and recovery and deployed and retrieved the mooring. Woods Hole personnel assisted and offered advice where necessary.

2.3 Mooring Installation and Recovery

2.3.1 Installation - The bathymetric survey of a line from the target mooring site six miles south was used to calibrate the depth sounder, establish the bathymetric features and to determine the roughness of the anchor area. Following this the vessel was positioned at the southern end of the track and the top sphere with radio and light put over. The vessel then got underway at 1345 Z October 26, 1976, on track north at 2 knots. Speed and course changes were given to the vessel by the range from the radar tracking station to enable the vessel to stay on track and to have all mooring components in the water except the anchor at point

(Bravo 5) ½ mile before the anchor drop point (Charlie 5). It will be seen however, that this phase was completed well before the drop point.

The mooring was paid out in a standard fashion while underway slowly. Terminations were stopped-off while instruments were shackled into the line. Groups of glass balls were inserted at two different levels to provide distributed buoyancy. Three Aanderaa current meters, two T/P recorders and four acoustic pingers were thus attached and deployed. Twenty-two glass balls above two parallel-mounted acoustic releases provided back-up recovery. At 1555 Z all components except the anchor were in the water. The anchor had a 40 pound Danforth tied to it with water soluble (PVA) rope to prevent tangling during descent. With the anchor on its launch skid and secured the vessel continued towing the mooring some 8000 yards to the anchor drop point. The speed with which the mooring was deployed coupled with an unexpected head current required this long tow. There were, however, no problems associated with the tow. The anchor drop point (Charlie 5) was reached at 1806 Z at which time the anchor was deployed. The final location of the mooring was close to the design position; quite acceptable in terms of water depth and distance from hydrophones and cables.

2.3.2 After Deployment - Following the anchor deployment the radio on the sphere was monitored until it went below the surface at 1819 Z. The range, tracking the pingers, notified the ship that the anchor bottomed out at 1826 Z, or 20 minutes after launch.

The vessel then proceeded to take XBT's each hour. Four acoustic dropsonde launches were also made.

2.3.3 Mooring Retrieval - The acoustic anchor release was fired at 0557 Z 27 October 1976, the mooring being on station 12 hours and 11 minutes. The sphere with radio and light both working normally surfaced

two minutes after release. At this time the wind was 18 knots from a direction of 060°T. The sea state was 4 to 6 with a 6 foot swell from 060°T. The retrieval operation began at 0732 Z with pickup of the sphere. All instruments were taken aboard in good condition. The last components to be brought aboard were the dual acoustic releases at 0912 Z. With reference to the Moored Station Logs, Figure 4, it can be seen that tangling occurred in each glass ball section. All instruments were washed down with fresh water and wiped off. Those having power switches were deactivated and the vessel headed for its berth.

2.4 Data Acquired

2.4.1 Current Meter Mooring - The current meter mooring operated satisfactorily throughout the period of the experiment. The T/P recorder at the top of the mooring was apparently bumped against the side of the vessel during launch which dislodged the tape cassette. Accordingly we are unable to determine this mooring lay-over or dip. It is thus not possible to accurately specify the depth of each current meter. However all five VACM current meters and the two Niskin current meters operated normally. The values of current measured by these instruments are such that there would be negligible layover or dip expected. Figures 5 through 9 show time series plots for the five VACM's for the DOCMS experiment interval. Figures 10 and 11 show speed and direction plots of all meters plus a Niskin current meter hand-smoothed to facilitate visual interpretation.

Inspection of these records indicates a highly variable current structure with both depth and time. Starting with launch (1800 Z) the current direction at all five VACM's was about due north. Over the next 14 hours the current direction at 200 meters gradually swung clockwise through south to west while the current at 500 meters changed very little gradually turning clockwise through east to about ESE. The current

No. 5

Set	Recovered
Date 26 OCT. 1976	Date 27 OCT. 1976
Time 1807 Zone GMT	Time 0912 Zone GMT
Lat. 22-10-14 Long. 154-56-36	Lat. 22-10-14 Long. 154-56-36
Observer/Recorder R.S. Walen	Observer/Recorder R.S. Walen
Watch Checked: Before ✓ After ✓	Watch Checked: Before ✓ After ✓
Set By R.H. Waldan	Retrieved By R.H. Waldan
Ship & Cruise No. De Steiguer 4	Ship & Cruise No. De Steiguer 4

Depth: Rec. Reading 165 fm. (m); Depth Corr. _____ Corr. m. 1701

Float Depth 261 Mag. Var. _____

Purpose of Mooring/Array DOCMS Mooring Validation

_____ Other Designations _____

Location Barking Sands Kauai, Hawaii Intended Duration 1 day Actual Days at Sea 1½ days

Main Float 44" Sphere Color(s) Orange Markings _____

No. of Glass-Sphere Clusters 3 Total No. of Spheres 51 Hat Color(s) Yellow

Wire 1/4" U.S.S. Torque Balanced

Rope 3/4" plaited Nylon

Radio Mfg. & No. OAR 2162 Tension Telemetry: Light Mfg. & No. OAR 1151

Freq. 27.095 MHz Type AM Strobe/Incand. White light

Char. _____ Code _____ Period _____ flashing every _____ seconds

AMF Release # 602045 503764 Time of Firing 27 OCT 1976, 0557 GMT

Receiver # 2 6 3 Remarks Int. 11.0 KHz. Disable Command 1 Int. 11.0 KHz, 45° Tilt Sen, Dis Comm. 1

Rel. Command 3

Anchors: Stimson _____ lbs. Other(s): Clump 325 lbs. Danforth 40 lbs.

Miscellaneous _____

Figure 4 Station Log

Station Number 5

Item No.	Length in m.	Item	Ident. No.	Over Time Over	Over Notes	Back Time Back	Back Notes	True Depth in m.	Date No.
1	1	4FT "Sphere 1058 3/4" Ball		1340		0732			
2	20M	2-10M 3/8" CHAIN		1332		0741			
3		Vandenag curr. meter	814	1352	Roter free 1352	0745			
4	2	3/8" Chain		1355					
5		S.C. Pinger Charlie	"C"	1355		0750			
6	63	1/4" W.R.		1359		0757			
7	23	23 glass balls		1412		0802	tangled		
8	10	3/8" Chain		1415					
9		Vandenag curr. meter	955	1418	Roter free 1417	0809			
10	2	3/8" Chain							
11		T/P #5	85	1421		0812			
12	2	3/8" Chain							
13		S.C. Pinger Delta	"D"	1426	on 1423	0816			
14	614	1/4" W.R.		1449		0833			
15	6	6 glass balls		1457		0849	Balls + pinger tangled		
16		D.C. Pinger Alpha	"A"	1458	on 1454	0831			
17	391	1/4" W.R.		1507		0857			
18		T/P #6	15	1512		0858			
19	2	3/8" Chain		1515					
20		DC Pinger Bravo	"B"	1515	on 1508	0901			

Date	Notes on Mooring, Sightings, Weather Difficulties, etc.
27 Oct	0557, Fixed 602045; Sphere up 0559. 0658 circling to come up on sphere (balls sighted w/searchlite. Grapnel hooked 0718. Sphere coming around to port and close in to stern. Sphere out of water 0731. Very windy.

Figure 4 (Cont.)

Station Number _____

Item No.	Length in m.	Item	Ident. No.	Over		Back		True Depth in m.	Data No.
				Time Over	Notes	Time Back	Notes		
21	2	3/8" Chain							
22		Aanderaa Cur. meter	957	1514	463 Vane + rotor from 1518	0904			
23	238	1/4" W.R.	1	1524		0911			
24	22	22 glass balls		1540		0912	tangled		
25		Acoustic release	503764	1551	pin out 1549	0912	Parallel		
26		Acoustic Release	602045	1551	pin out 1549	0912	"		
27	5	1/2" Chain							
28	20	3/4" nylon		1554					
29	3	1/2" Chain		1558					
30		3250# Clump							
31	10	3/8" Chain							
32		40# Danforth		1807					

Date	Notes on Mooring, Sightings, Weather Difficulties, etc.
26 Oct.	Buoy went under at 1818
	Brass Pinger coordinates
	Lat. 22-10-14.5 Long 159-56-36.5

Figure 4 (Cont.)

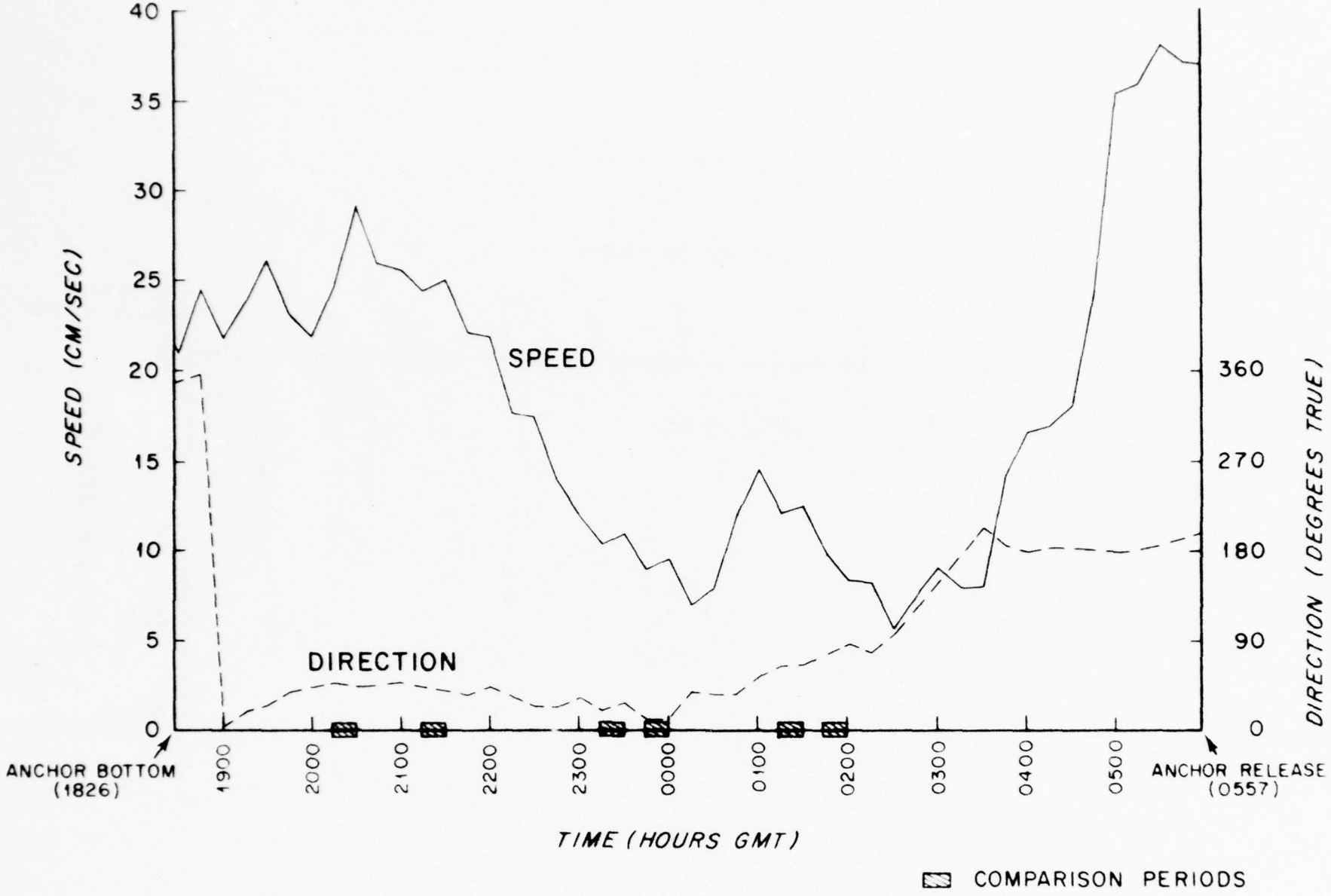


Figure 5 VACM 295 (200 m)

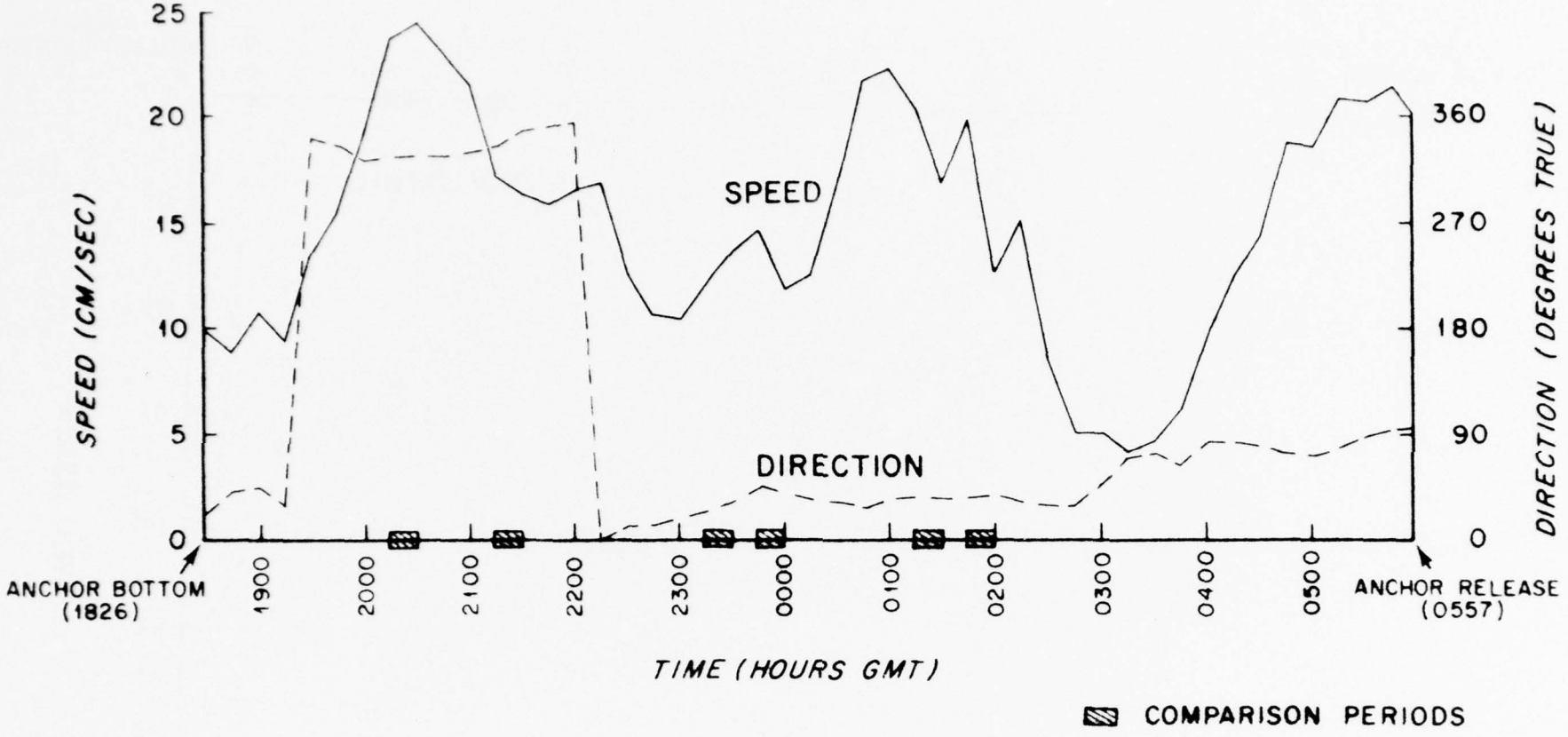


Figure 6 VACM 293 (500 m)

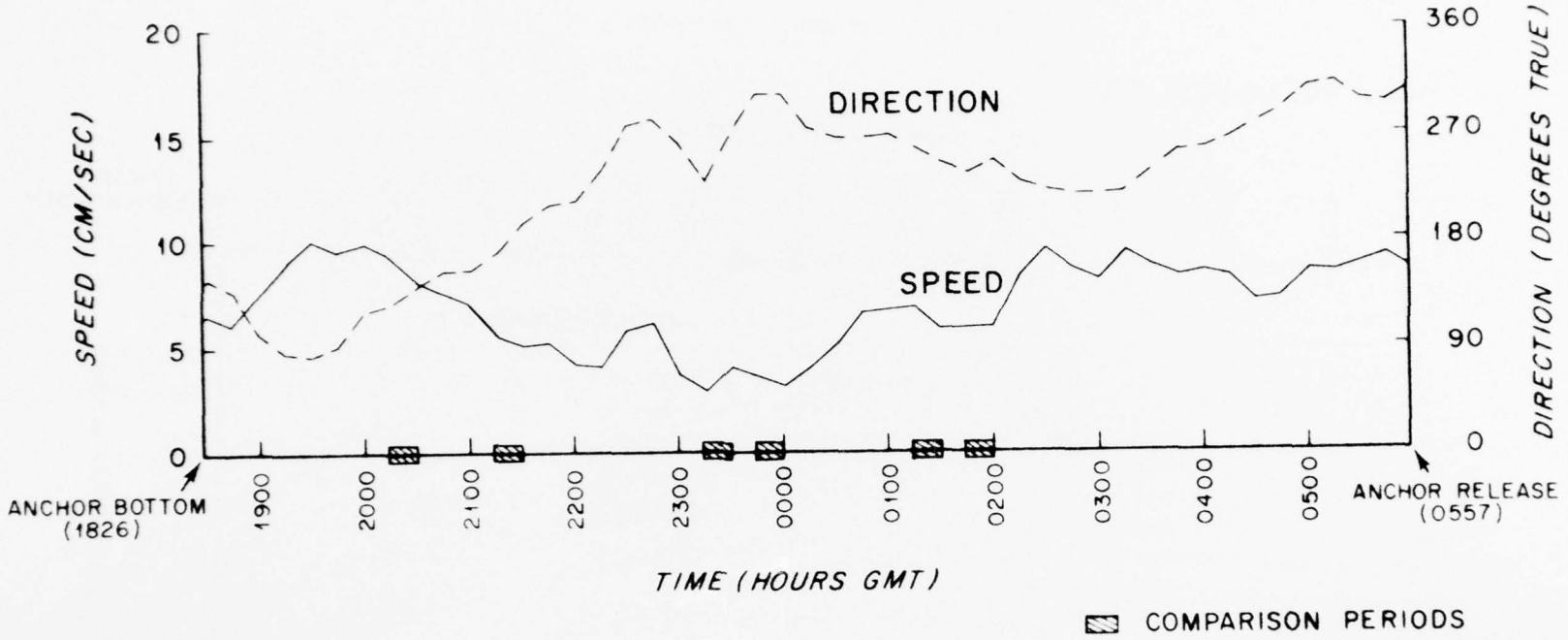


Figure 7 VACM 264 (750 m)

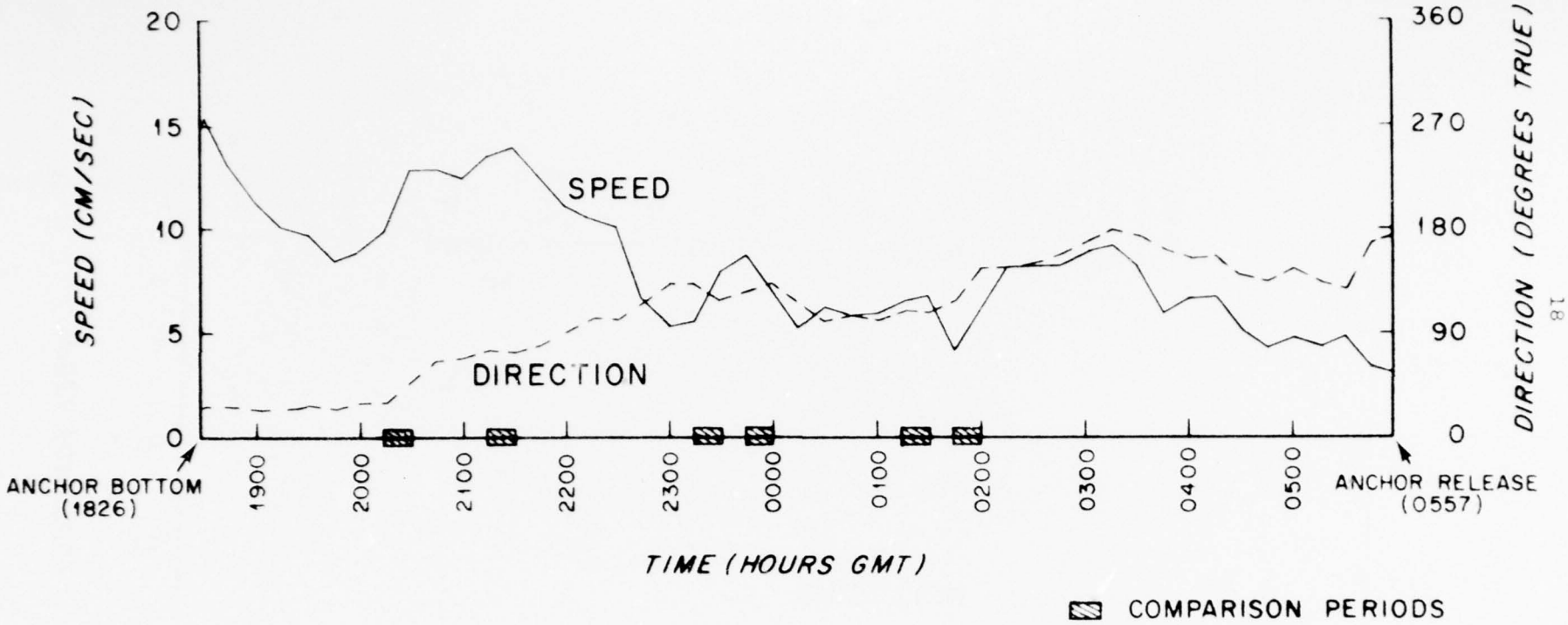


Figure 8 VACM 253 (1000 m)

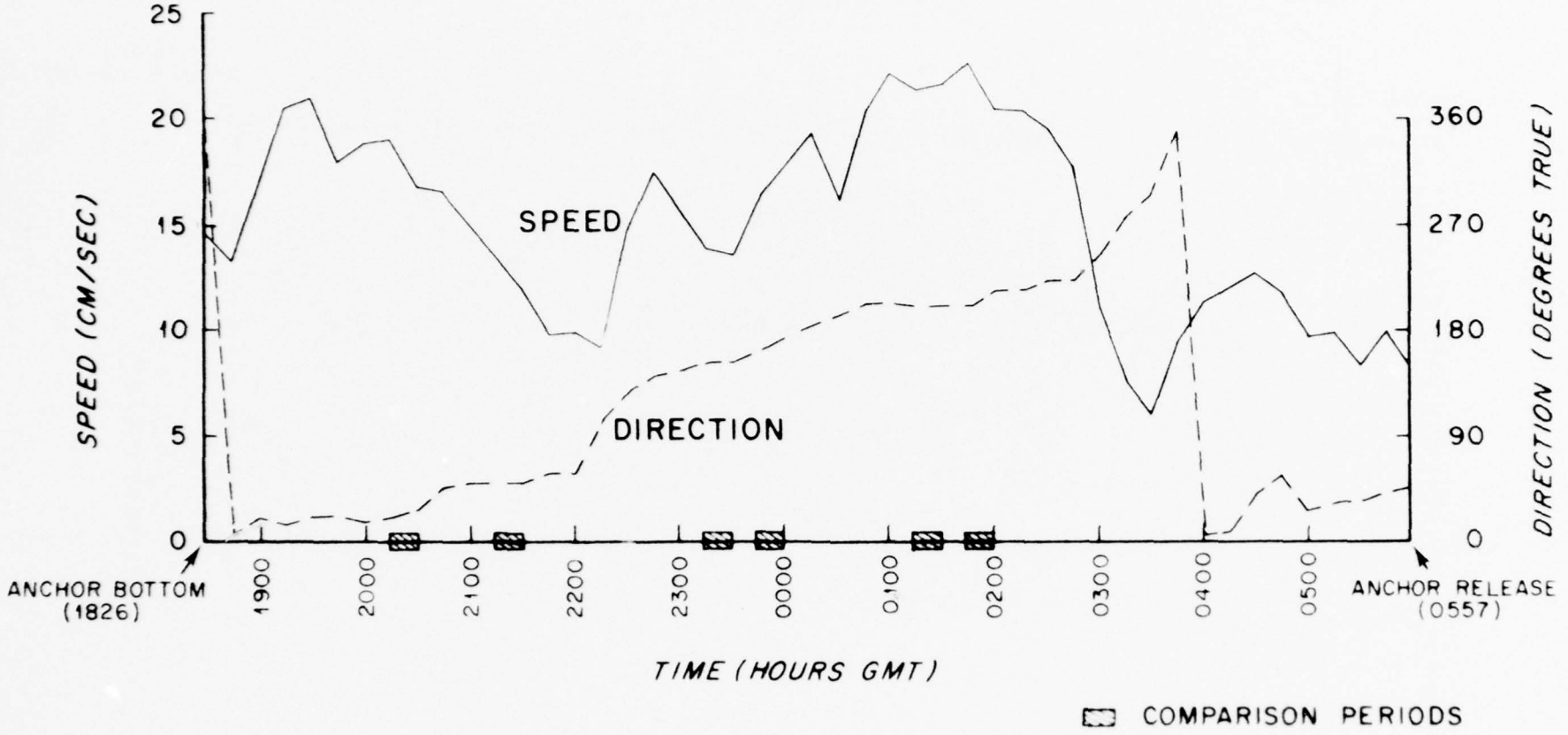


Figure 9 VACM 290 (1300 m)

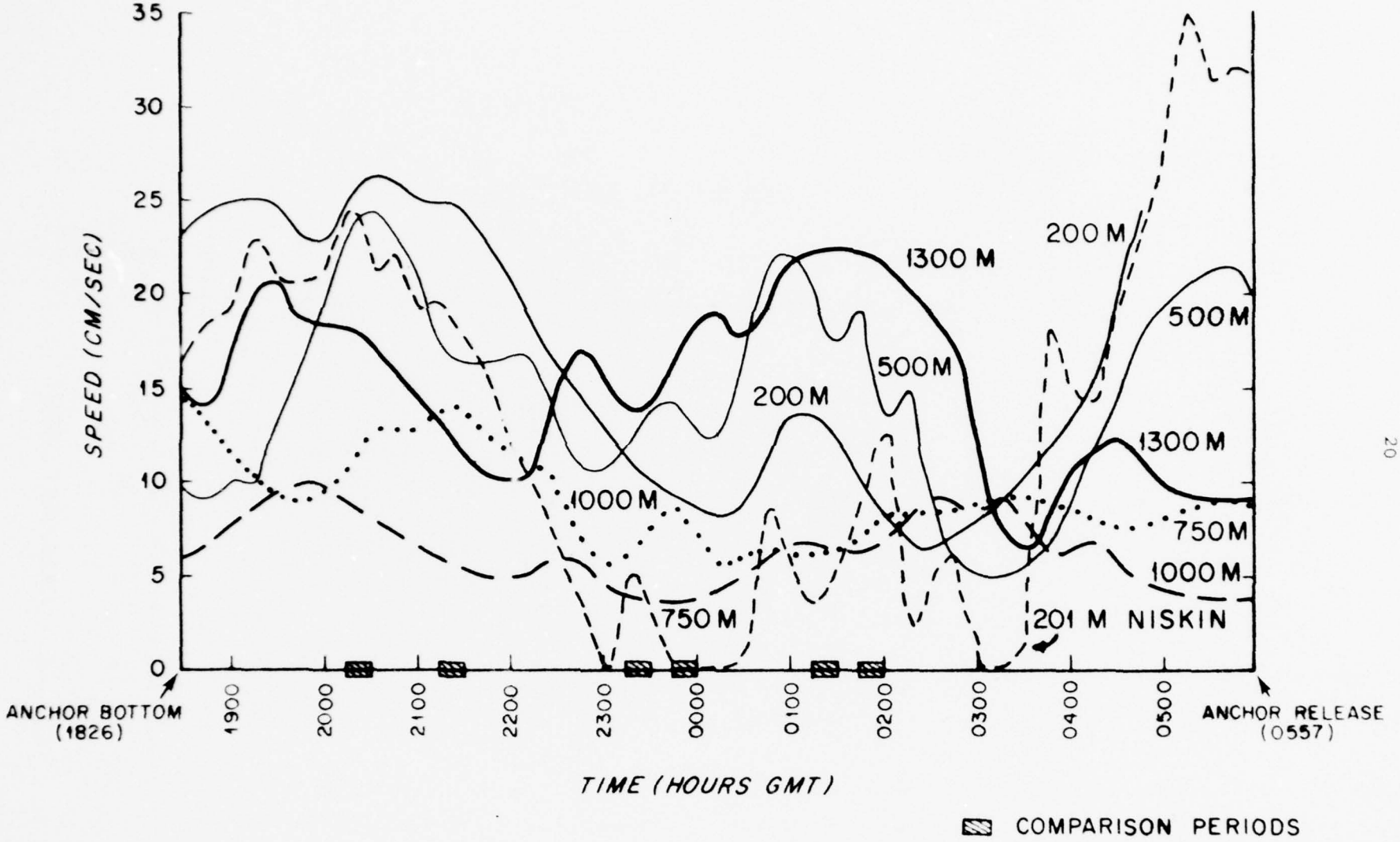


Figure 10 VACM & Niskin Eyeball Speed Averages

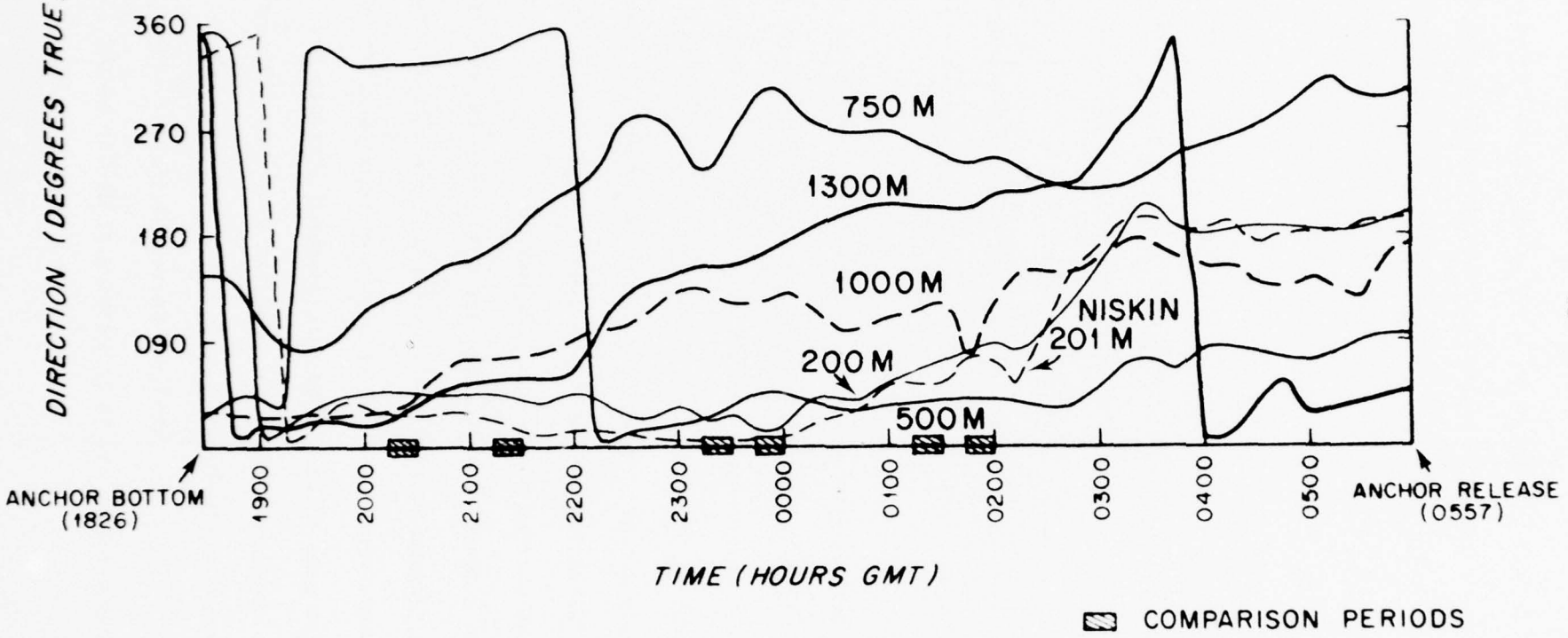


Figure 11 VACM & Niskin Eyeball Direction Averages

direction at 750 meters started out about east, rotated clockwise to west in about four hours and remained in the northwest quadrant for the remainder of the record. The current direction at 1000 meters rotated gradually clockwise from north to nearly west. During this same time the direction at 1300 meters rotated clockwise from north 360° in nine hours and then continued its clockwise rotation towards east very slowly. The broad picture is one showing currents at all depths rotating clockwise, with the current at 1300 meters indicating the clearest tidal signature. Tidal events are present at all depths except possibly at 500 meters, but are not well defined because of the short record length. Attention is drawn to Appendix 1 (VACM Data Summaries) for a more comprehensive understanding of the current structure over the 21.7 days during which the current meter mooring was in.

The current speeds can similarly be seen to have large shears in the vertical. The highest currents were experienced near the end of the DOCMS experiment. The current speed at 200 meters was nearly 40 cm/sec at this time. The value at this depth was about 25 cm/sec at the beginning of the experiment. The lowest current speed measured during the experiment was 5 cm/sec at 750 and 1000 meters. The speed at 1300 meters was consistently higher than the current at 750 and 1000 meters.

The VACM's recorded vector averages once each fifteen minutes. Data from six time periods were selected during the experiment consisting of these 15 minute averages. These values were compared with the Aanderaa values at these same times. Dropsonde computed currents were compared with both the upper two VACM's and Aanderaa's at four different times.

2.4.2 DOCMS Mooring

2.4.2.1 Aanderaa Current Meters - Three Aanderaa current meters were installed on the DOCMS mooring at depths of 282, 373 and 1405

meters. All meters appeared to function normally. The recording interval was 1/minute, speed being averaged and direction taken instantaneously at the end of the interval. Time series of speed and direction of all meters are shown (Figures 12 - 19) with one minute sampling and hand smoothed averages for general recognition of trends.

The current direction of the meter at 282 meters started out a little south of east, rotated clockwise towards north, back towards east and again clockwise towards north. The current speed for this meter varied from a low of 5 cm/sec to a high of 15 cm/sec. The current direction at 373 meters started out at south proceeding clockwise through north six hours later repeating the cycle over the next six hours. The current speed at this level varied between two and 15 cm/sec. The current direction at 1405 meters started out nearly north turning slightly to the west, back to north and then clockwise to south for around six hours. The speeds were 5 to 10 cm/sec for the first six hours increasing to nearly 20 cm/sec before decreasing again. This current meter appeared to develop trouble towards the end of the record. Figures 12, 13 and 14 show the time series plots furnished by NUSC. They contain speed, direction, pressure and temperature. Figures 15 and 16 are handsmoothed plots of speed and direction only for feature recognition. Figures 17, 18 and 19 are expanded time series plots of direction and speed for the three meters.

2.4.2.2 Acoustic Pingers - Four acoustic pingers were furnished by the Naval Torpedo Station Detachment Hawaii. These were attached to the mooring at 285, 379, 1004 and 1401 meters. X and Y ranges from a datum point within the range were obtained by the range once per second for the complete experiment duration from each pinger. In addition a depth measurement was obtained for each pinger every second. All pingers worked satisfactorily throughout the experiment duration. The vertical mooring motion or dip for six different times have been determined and are

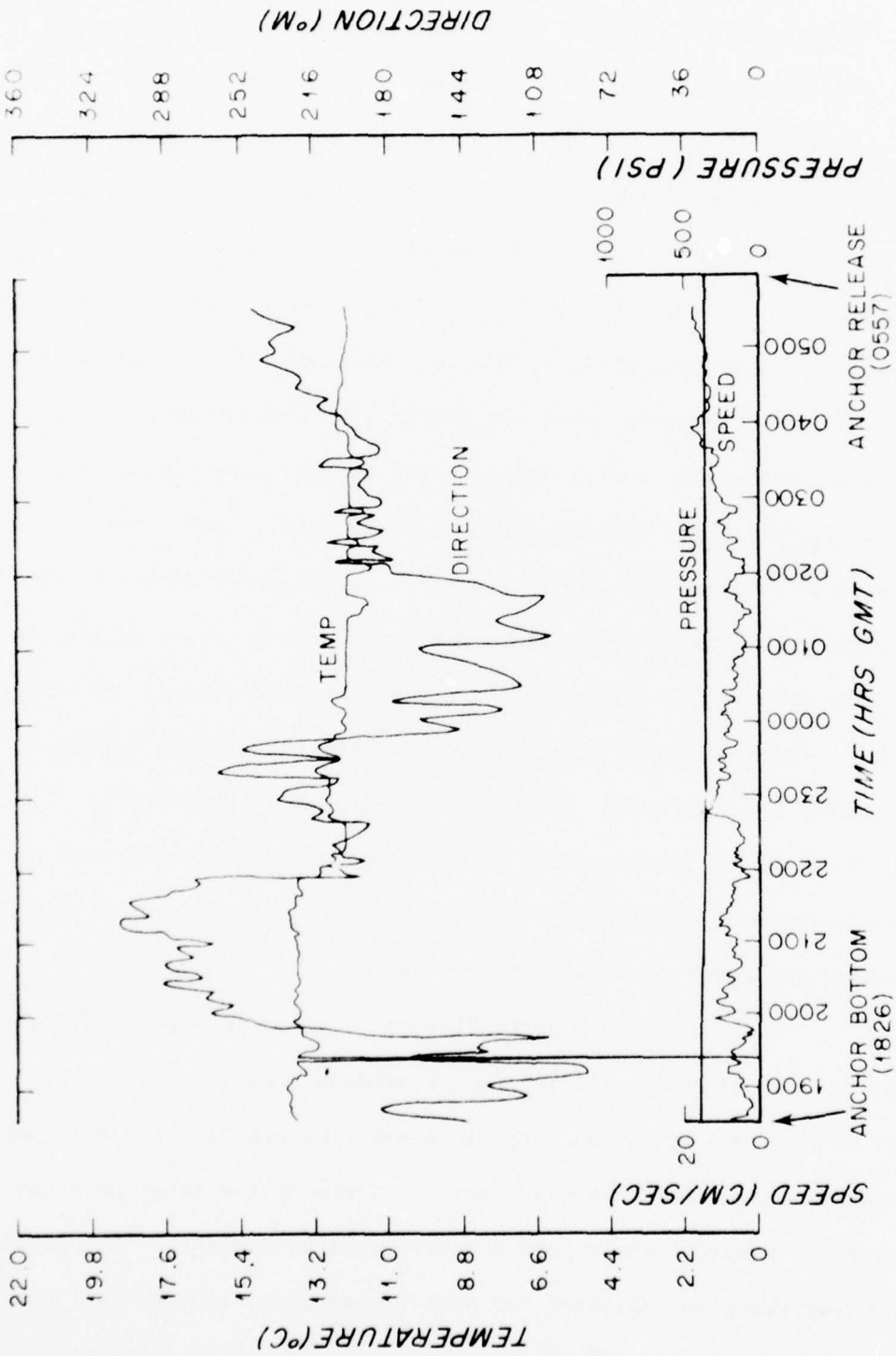


Figure 12 Top Aanderaa (282 m)

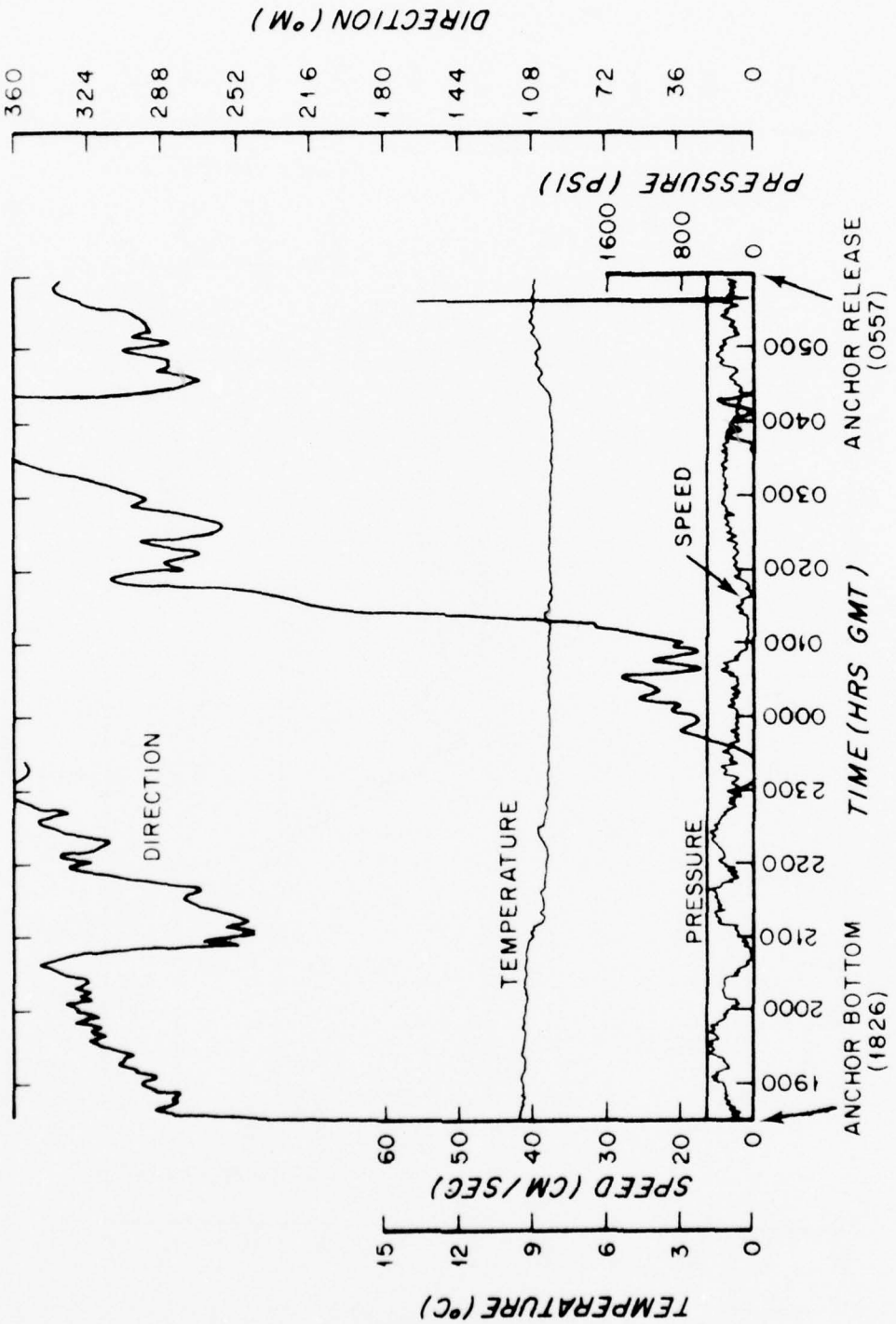


Figure 13 Middle Aanderaa (373 m)

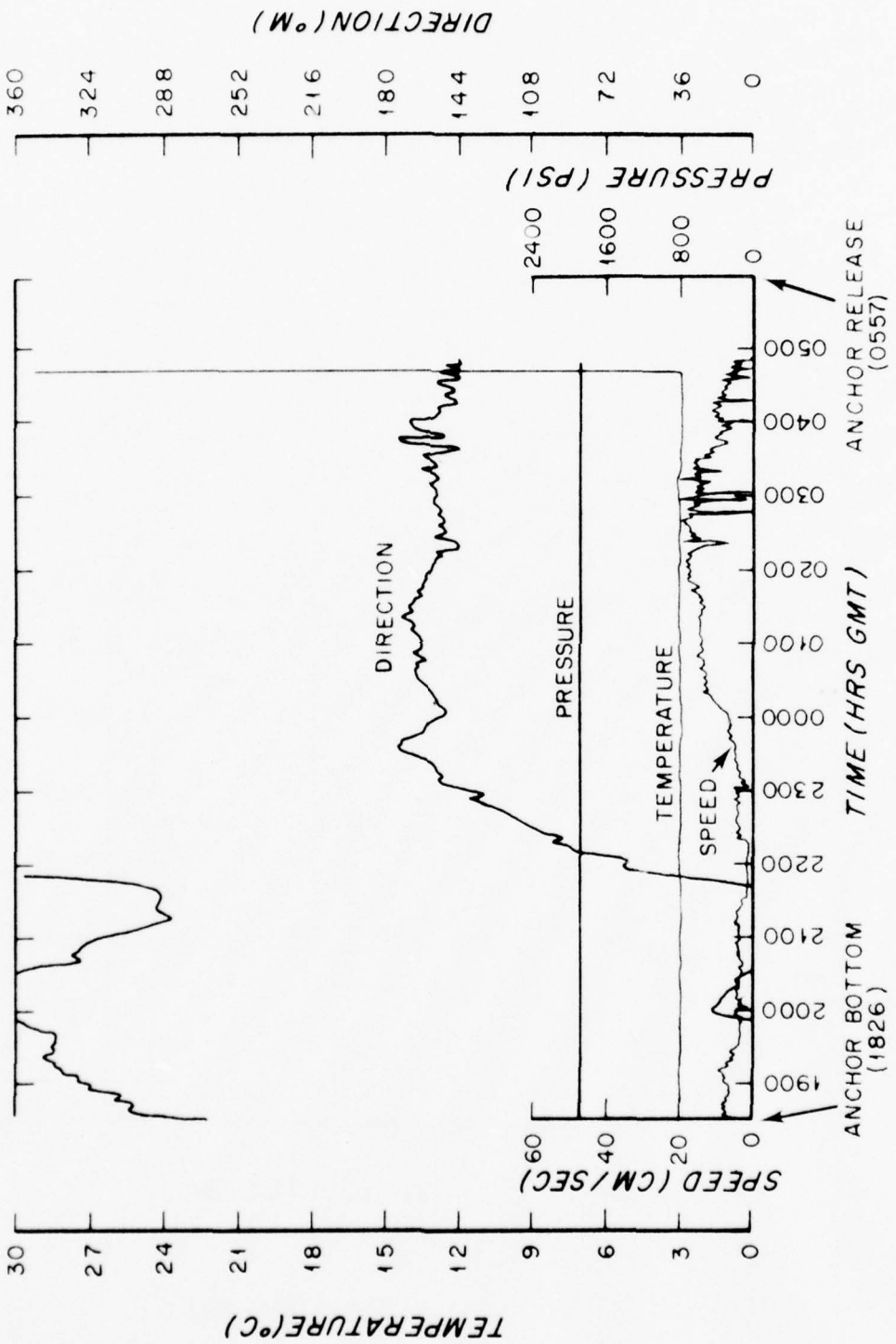


Figure 14 Lower Aanderaa (1405 m)

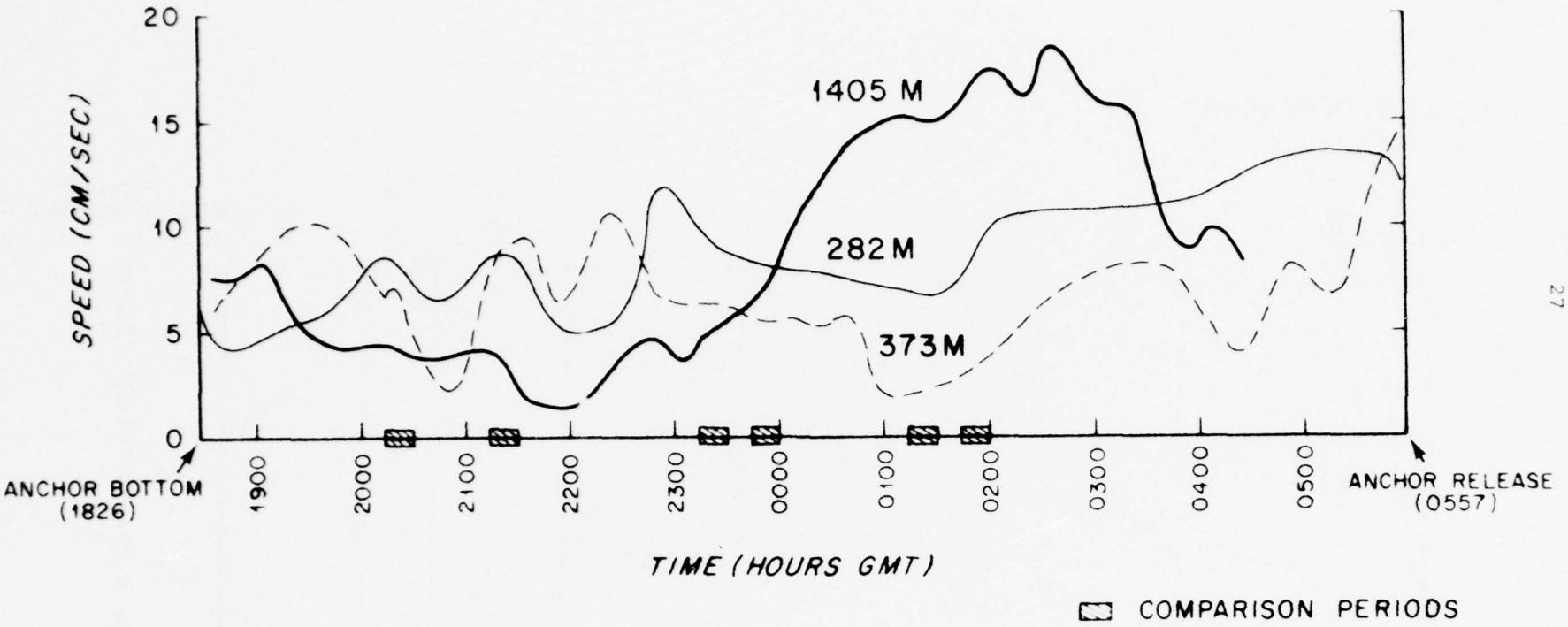


Figure 15 Aanderaa Speeds

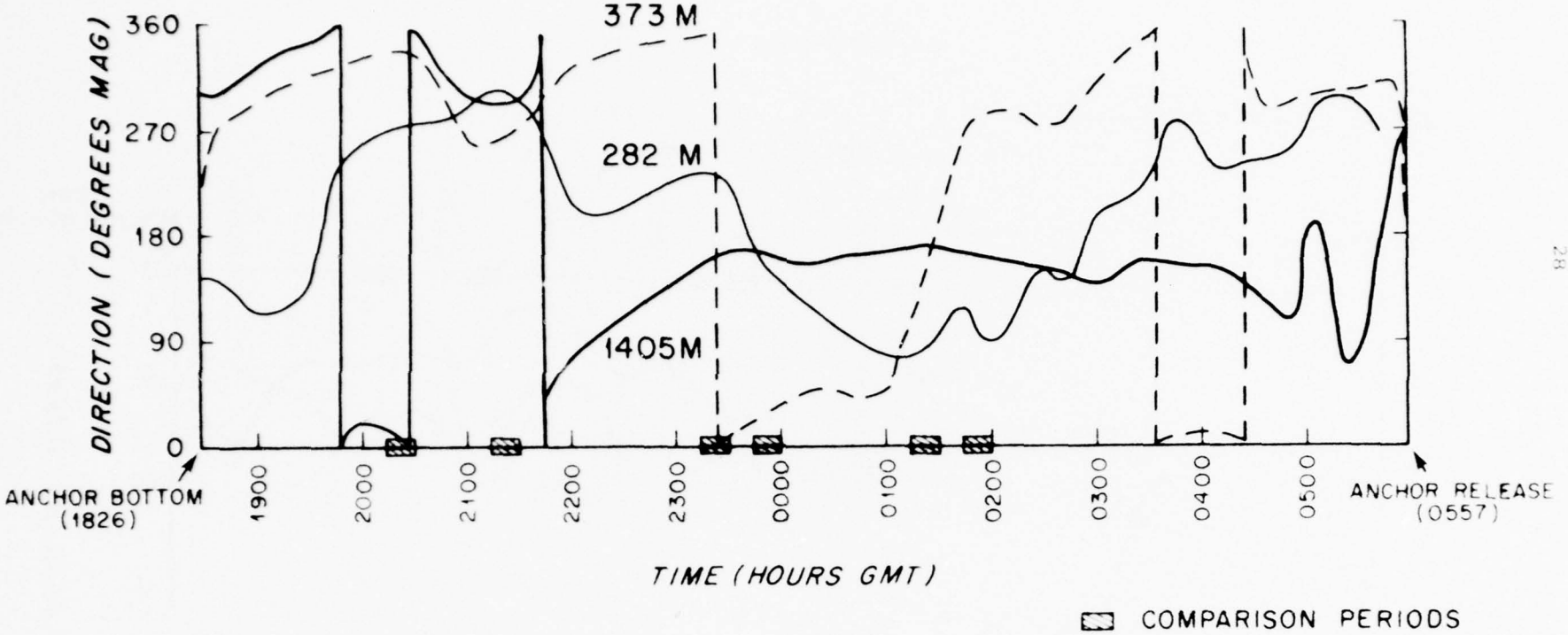


Figure 16 Aanderaa Directions

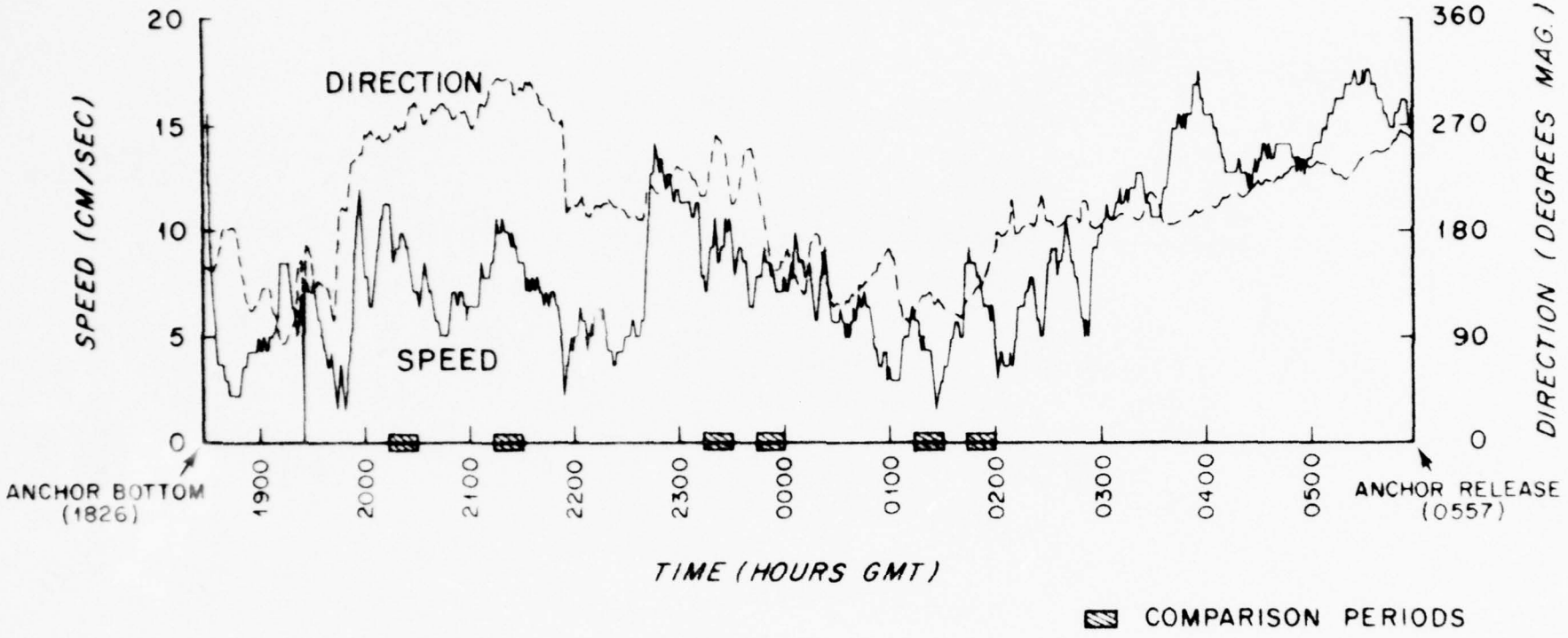


Figure 17 Top Aanderaa (282 m)

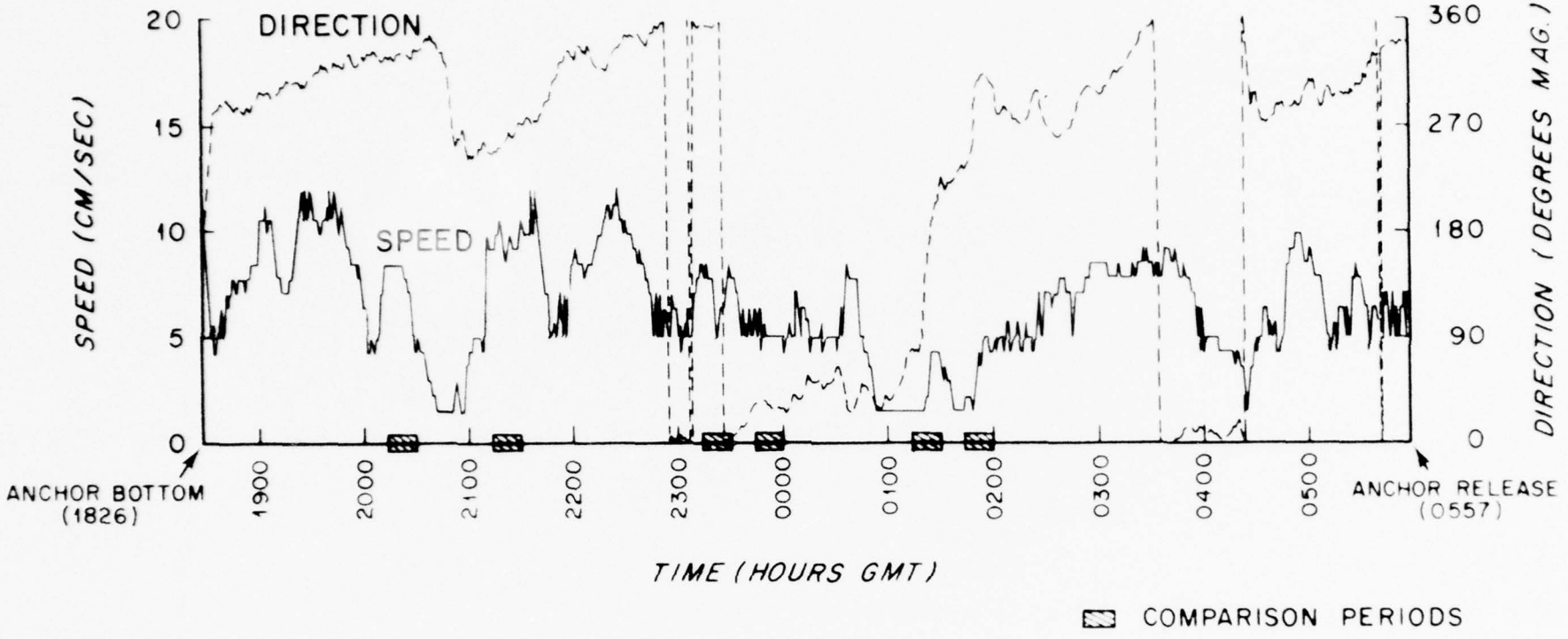


Figure 18 Middle Aanderaa (373 m)

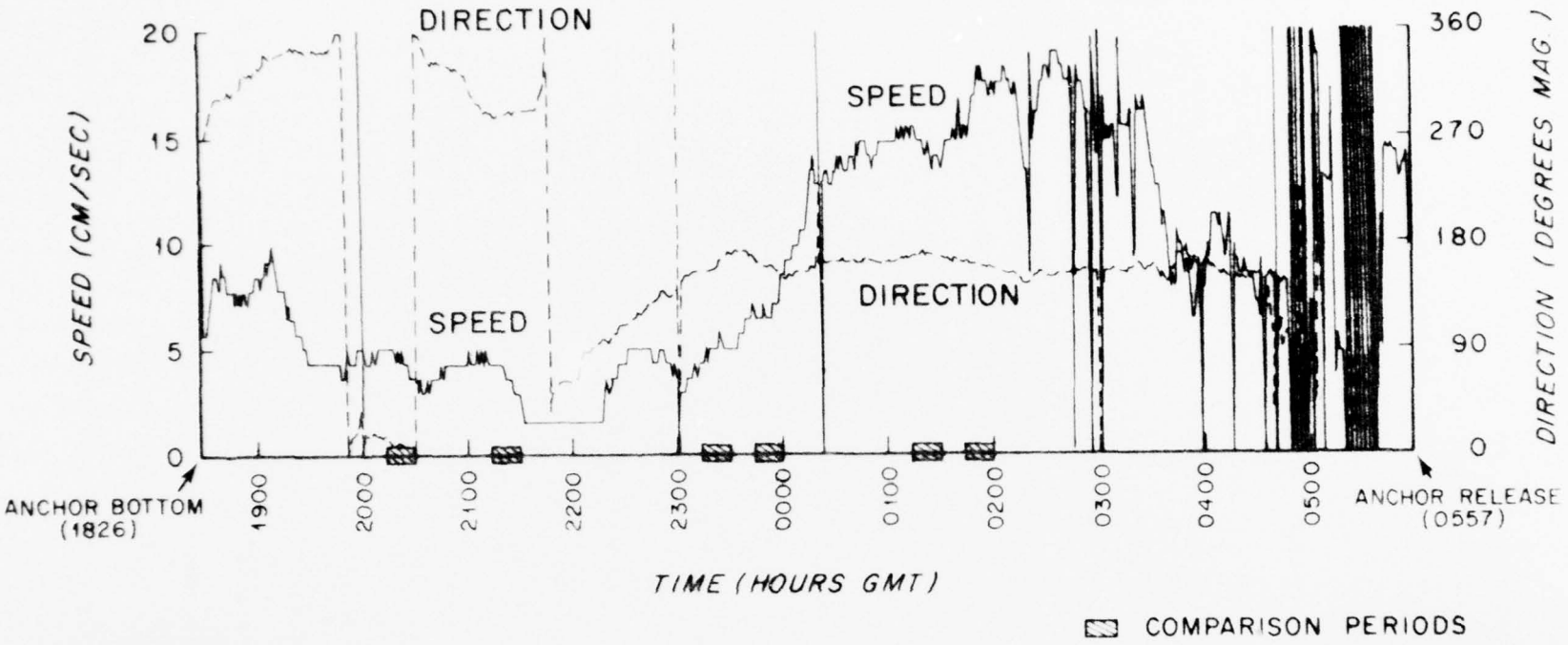


Figure 19 Bottom Aanderaa (1405 m)

discussed under Section 4.1. Excursions from an estimated anchor location in X and Y coordinates are shown in Section 4.2. Trajectories of the pingers during launch and recovery are discussed in Sections 4.3 and 4 4. Standard sound velocity corrections were applied to all acoustic range data by PMRF at the time of the experiment. Temperatures obtained during the experiment are now available to provide to the range for rerunning the acoustic data with a more accurate sound profile This report has been prepared based upon ranges obtained using the standard profile.

2.4.2.3 Temperature/Pressure Recorders - Two temperature/pressure recorders were attached to the mooring at 376 and 1397 meters. Both worked normally. Table 9 shows the T/P indicated depth for both recorders for no current and six different profiles obtained from the data at the comparison times shown on Figures 12 - 19.

2 4.2.4 Acoustic *Dropsondes* - Four dropsonde drops were made during the experiment. All worked satisfactorily. The drops were all to a depth of 500 meters +1 and -12 meters. Figures 20 through 23 show the current speed for descent and ascent as a function of depth for each drop. The current direction for both ascent and descent is shown in the right hand margin.

2.4.3 Comparison of Current Measurements - Current measurements were taken at the current meter mooring, on the DOCMS mooring and by means of an acoustic dropsonde. An intercomparison of these three source measurements were made in order to assess their quality and to determine the degree of horizontal coherence between measurement points. Four times were selected to coincide with dropsonde measurements. Table 1 shows these four comparisons. During each dropsonde a measurement of current speed and direction is listed for a depth at which a current meter, either on the current meter mooring or on the DOCMS mooring was located.

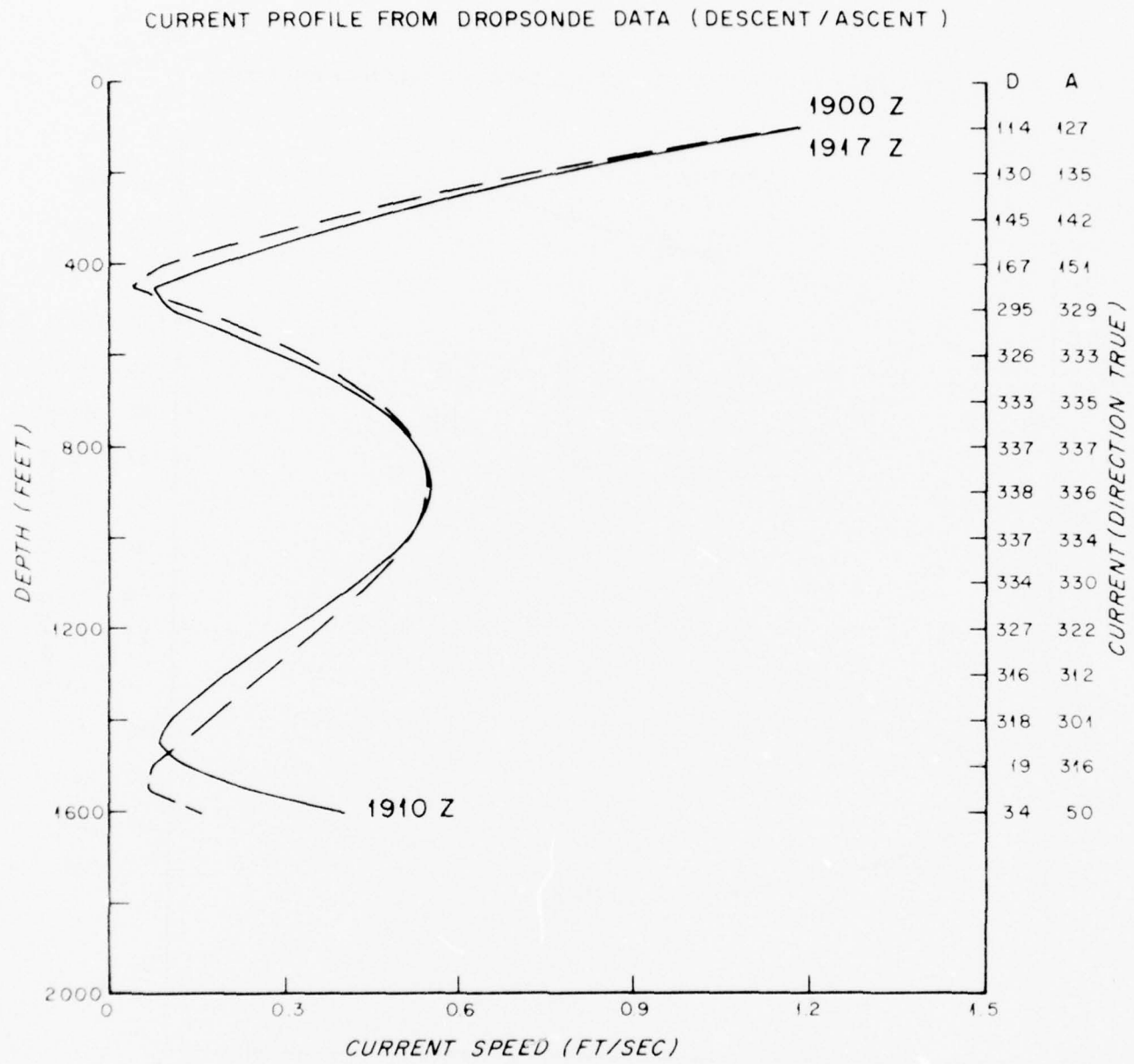


Figure 20 Dropsonde #1

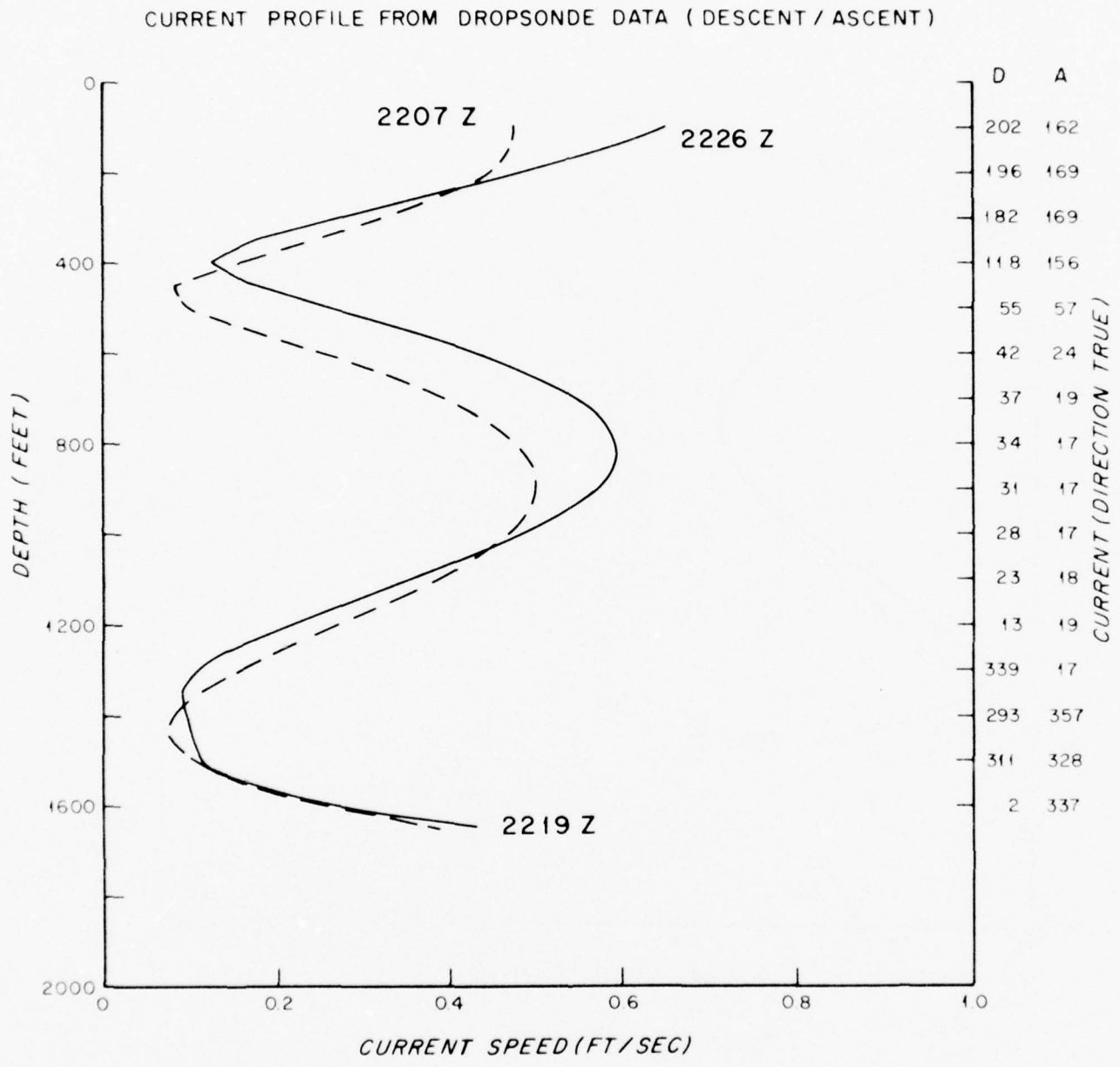


Figure 21 Dropsonde #2

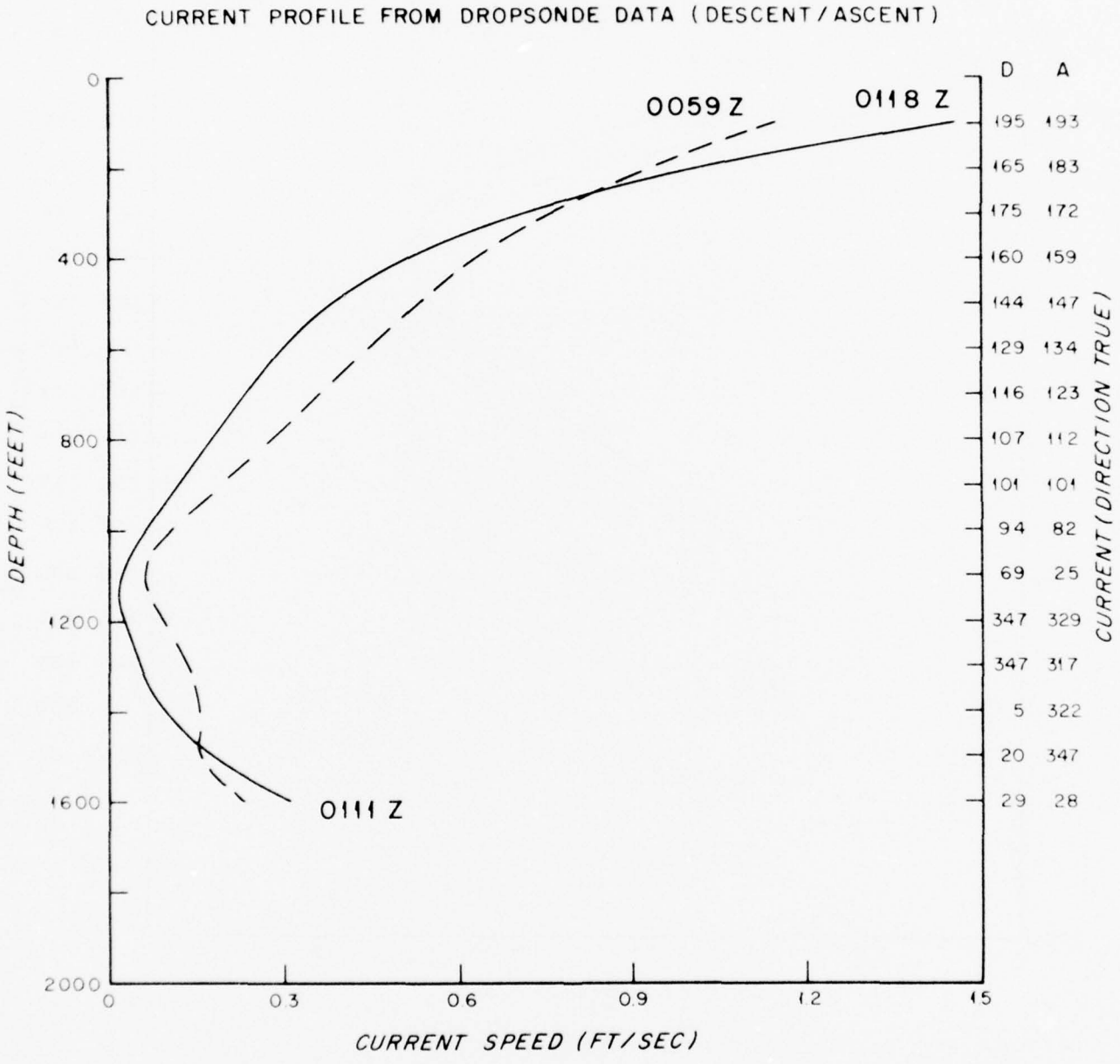


Figure 22 Dropsonde #3

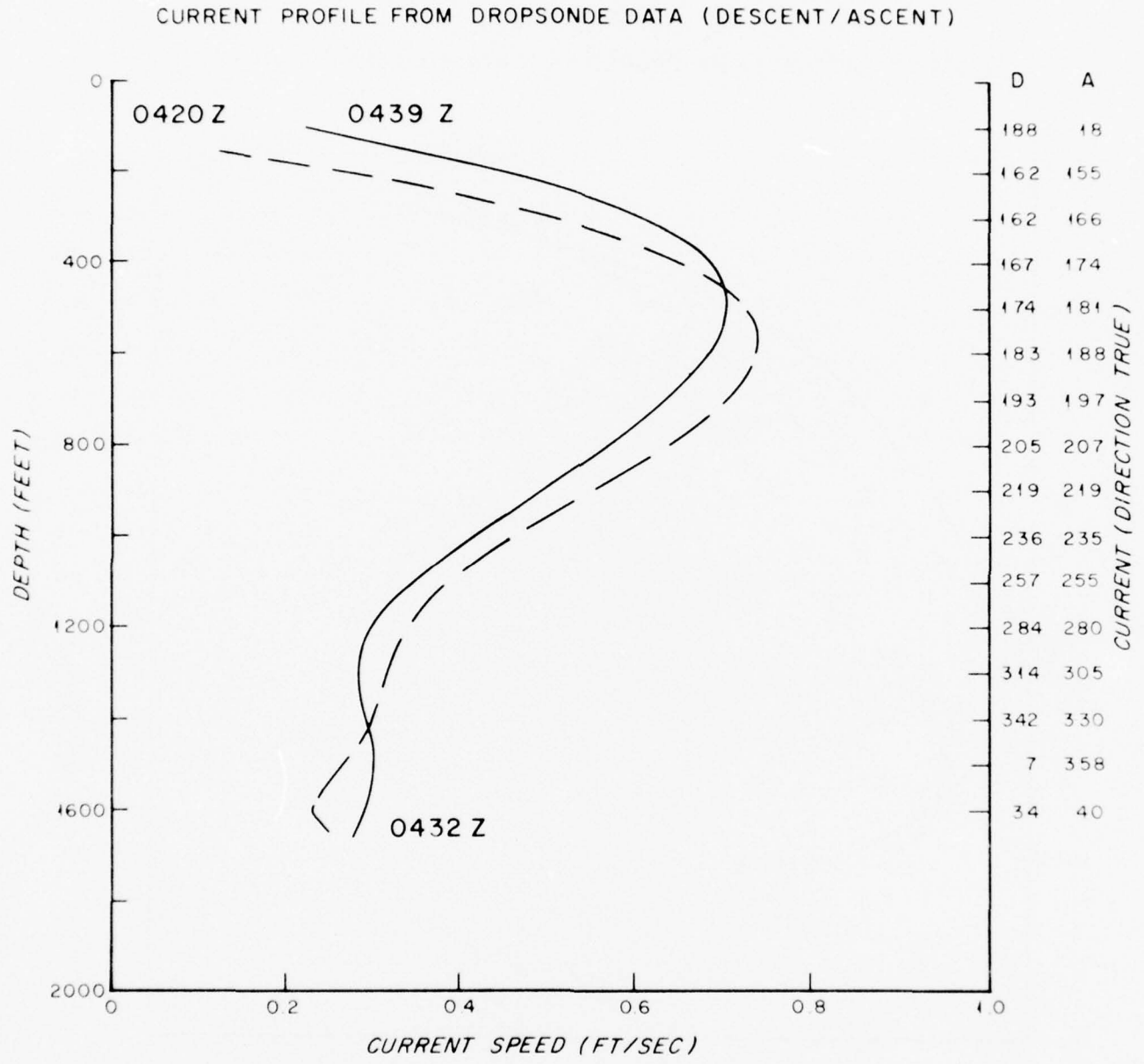


Figure 23 Dropsonde #4

TIME (z)	DEPTH (m)	DROPSONDE		DOCMS MOORING AANDERAAS		CURR METER MOOR VACMS		DROPSONDE LOCATION
		SPEED (cm/sec)	DIR (°true)	SPEED (cm/sec)	DIR. (°true)	SPEED (cm/sec)	DIR. (°true)	
1903	200	11.6	330°			21.8	003°	#I Drop .6 Miles East of Mooring
1905	282	17.1	338°	5.0	142°			
1907	373	9.5	327°	10.6	303°			
1910	500	12.2	035°			9.4	028°	
2212	200	15.2	039°			17.6	033°	#II Drop .6 Miles East of Mooring
2214	282	17.4	031°	6.4	211°			
2216	373	6.4	013°	9.9	331°			
2219	500	13.4	013°			16.9	001°	
0104	200	8.2	122°			14.5	053°	#III Drop .7 Miles East of Mooring
0106	282	3.7	100°	2.9	128°			
0108	373	1.0	347°	1.5	069°			
0111	500	9.5	029°			20.4	037°	
0425	200	20.1	188°			18.1	182°	#IV Drop .5 Miles East of Mooring
0427	282	15.2	219°	12.7	230°			
0429	373	9.4	284°	12.7	234°			
0432	500	8.5	052°			14.3	080°	

(Table I) DROPSONDE AND CURRENT METER COMPARISON

Inspection of this table quickly leads one to the conclusion that the current structure in the area is indeed turbulent. Certainly there seems to be poor horizontal coherence. We have no evidence to indicate that instrumental measuring errors are present in any of the data presented. The last column of the table shows the location of the dropsonde in relation to the DOCMS mooring.

3.0 Prediction of Mooring Motions

3.1 Pre-Experiment - The mooring was designed using the NOYFB computer program. The computer listing and printout for this design is enclosed as Appendix 2. It will be noted that two cases were run, one with no current and the other with a uniform non-rotating current of 50 cm/sec from surface to bottom. Column 5 on the mooring statistics - Summary Page - shows the depth of each component listed serially in Column 1. Column 2 indicates the type of component. The number and component type is identified as follows.

Component	Type	
1	36	44 1050# AL sphere
2	22	20 m 3/8" chain
3	25	Aanderaa Current Meter
4	22	2 m 3/8" chain
5	33	Subcan Pinger "Charlie"
6	2	63 m ½" wire rope
7	40	(23) 17" Glass Balls on 23 m 3/8" chain
8	25	Aanderaa Current Meter
9	22	2 m 3/8" chain
10	37	T/P Recorder
11	22	2 m 3/8" chain
12	33	Subcan Pinger "Delta"
13	2	614 m ½" wire rope
14	40	(6) 17" Glass Balls on 6 m 3/8" chain
15	34	Deep Can Pinger "Alpha"
16	2	391 m ½" wire rope
17	37	T/P Recorder
18	22	2 m 3/8" chain
19	34	Deep Can Pinger "Bravo"
20	22	2 m 3/8" chain
21	25	Aanderaa Current Meter
22	2	237 m ½" wire rope

23	40	(22) 17" Glass Balls on 22 m 3/8" chain
24	35	Dual Releases in Parallel
25	23	5 m ½" chain
26	15	20 m 3/4" chain
27	23	3 m ½" chain

Referring to the Mooring Statistics - Summary Sheet for zero current the depth of the top sphere was 259.8 meters. At 50 cm/sec from top to bottom (second Mooring Statistics - Summary Sheet) the computed depth was 299.9 meters or a dip of 40.1 meters. The horizontal excursion was 312.7 meters.

3.2 Post-Experiment - Following the experiment similar computer runs were made using actual current measurements made at the time of the experiment. Profiles were generated from the current meter mooring and the DOCMS mooring and separately used as inputs to the program. Six times were chosen from the time series records (Figures 5 - 9 and 17 - 19) and profiles obtained. Each time slot represents a 15 minute average of current speed and an instantaneous measurement of direction for the Aanderaa meters. A fifteen minute vector average was used for the VACM's. These time slots were chosen from the records on the basis of medium and high currents and minimum variability. The current profiles obtained for the validation are listed in Tables 2 - 4. When direction changes were large between adjacent instruments, two cases were run, rotating the current in each direction in that depth interval.

4.0 Discussion of Results

As mentioned above, current profiles from the two mooring sources were developed and inputted into the mooring design computer program. Tables 5 - 8 show the current profile numbers and observation times used with each case (one or two, see 3.2). Each table compares the computed value (COMP) of depth, X excursion, and Y excursion for each of the four pingers from a "best-estimate" (RANGE) anchor position. The top line in each

PROFILE #	TIME , DATE	MOORING	DEPTH (meters)	SPEED (cm/sec)	DIRECTION (° true)	
					CASE 1	CASE 2
1	0000 Z 27 OCT 1976	CURRENT METER (VACMS)	0	9.5	370	370
			200	9.5	370	370
			500	11.9	399	399
			750	3.1	305	305
			1000	7.1	493	133
			1300	17.8	535	175
			1701	17.8	535	175
		DOCMS (AANDERAAS)	0	8.5	142	
			282	8.5	142	
			373	4.8	039	
			1405	8.3	161	
			1701	8.3	161	
2	2030 26 OCT 1976	CURRENT METER (VACMS)	0	29.3	403	403
			200	29.3	403	403
			500	24.5	327	327
			750	8.1	143	503
			1000	12.9	049	409
			1300	16.8	027	387
			1701	16.8	027	387
		DOCMS (AANDERAAS)	0	6.7	296	
			282	6.7	296	
			373	4.6	345	
			1405	3.7	371	
			1701	3.7	371	

(Table 2) CURRENT PROFILES 1 AND 2

PROFILE #	TIME, DATE	MOORING	DEPTH (meters)	SPEED (cm/sec)	DIRECTION (°true)	
					CASE 1	CASE 2
3	0130 Z 27 OCT 1976	CURRENT METER (VACMS)	0	12.5	425	425
			200	12.5	425	425
			500	16.9	395	395
			750	5.9	247	247
			1000	6.8	107	467
			1300	21.6	200	560
			1701	21.6	200	560
		DOCMS (AANDERAAS)	0	3.5	123	
			282	3.5	123	
			373	3.3	228	
			1405	14.2	176	
			1701	14.2	176	
4	2330 Z 26 OCT 1976	CURRENT METER (VACMS)	0	10.9	387	387
			200	10.9	387	387
			500	13.7	393	393
			750	4.1	272	272
			1000	8.0	478	118
			1300	13.5	512	152
			1701	13.5	512	152
		DOCMS (AANDERAAS)	0	9.2	215	
			282	9.2	215	
			373	8.1	374	
			1405	5.0	543	
			1701	5.0	543	

(Table 3) CURRENT PROFILES 3 AND 4

PROFILE #	TIME, DATE	MOORING	DEPTH (meters)	SPEED (cm/sec)	DIRECTION (° true)	
					CASE 1	CASE 2
5	0200 Z 27 OCT 1976	CURRENT METER (VACMS)	0	8.3	446	
			200	8.3	446	
			500	12.7	398	
			750	5.9	249	
			1000	6.1	146	
			1300	20.4	213	
			1701	20.4	213	
		DOCMS (AANDERAAS)	0	5.5	174	
			282	5.5	174	
			373	4.6	308	
			1405	17.5	169	
			1701	17.5	169	
6	2130 Z 26 OCT 1976	CURRENT METER (VACM'S)	0	25.1	038	
			200	25.1	038	
			500	16.4	347	
			750	5.1	196	
			1000	14.0	073	
			1300	11.9	050	
			1701	11.9	050	
		DOCMS (AANDERAAS)	0	8.5	314	
			282	8.5	314	
			373	10.2	283	
			1405	2.4	304	
			1701	2.4	304	

(Table 4) CURRENT PROFILES 5 AND 6

CURRENT PROFILE #	MOORING	TIME (Z)	"C" PINGER DEPTH (m)		"C" PINGER X EXCURSION (m)		"C" PINGER Y EXCURSION (m)		COMMENTS
			COMP.	RANGE	COMP	RANGE	COMP	RANGE	
					E components pos.		N components pos.		
0			285.0	297.5	0	0	0	0	ANCHOR COORDINATES X=(-)7186 Y=17532 DATUM HS 3-4
1	CM	0000	285.1	302	5.1	1	4.1	0.9	CASE 1
1	CM	0000	235.1		4.8		3.7		CASE 2
1	DOCMS	0000	285.0		-1.2		3.7		
2	CM	2030	285.9	298.4	48.0	-7	12.9	14.6	CASE 1
2	CM	2030	286.1		51.6		18.4		CASE 2
2	DOCMS	2030	285.0		1.9		-1.5		
3	CM	0130	285.1	301.7	4.2	-1.2	11.8	-4.3	CASE 1
3	CM	0130	285.1		4.9		11.8		CASE 2
3	DOCMS	0130	285.1		-5.6		-1.3		
4	CM	2330	285.1	301.4	8.5	0	7.2	3.0	CASE 1
4	CM	2330	285.1		7.9		7.0		CASE 2
4	DOCMS	2330	285.0		1.3		0.4		
5	CM	0200	285.1	301.8	-1.4	-4.3	4.9	-3.0	
5	DOCMS	0200	285.1		-4.7		-4.5		
6	CM	2130	285.1	301.4	-11.3	-6.4	5.7	7.6	
6	DOCMS	2130	285.1		4.3		-6.9		

(Table 5) "C" PINGER POSITION DATA

CURRENT PROFILE #	MOORING	TIME (Z)	"D" PINGER DEPTH (m)		"D" PINGER X EXCURSION (m)		"D" PINGER Y EXCURSION (m)		COMMENTS
			COMP.	RANGE	COMP.	RANGE	COMP.	RANGE	
					E. components pos.		N. components pos.		
0			379.4	404.6	0	0	0	0	ANCHOR COORDINATES X=-7186 Y=17532 DATUM HS 3-4
1	CM	0000	379.5	407.0	4.7	0.3	4.0	0.6	CASE 1
1	CM	0000	379.4		4.4		3.6		CASE 2
1	DOCMS	0000	379.4		-1.1		3.6		
2	CM	2030	380.3	404.6	45.7	-7.0	11.8	14.3	CASE 1
2	CM	2030	380.5		49.3		17.3		CASE 2
2	DOCMS	2030	379.4		1.8		-1.3		
3	CM	0130	379.3	407.3	3.8	-1.2	11.2	-4.3	CASE 1
3	CM	0130	379.5		4.6		11.3		CASE 2
3	DOCMS	0130	379.4		-5.6		-1.3		
4	CM	2330	379.5	408.5	8.1	-0.9	7.0	2.4	CASE 1
4	CM	2330	379.5		7.5		6.8		CASE 2
4	DOCMS	2330	379.4		1.4		0.6		
5	CM	0200	379.5	406.7	-1.5	-4.3	4.6	-3.4	
5	DOCMS	0200	379.5		-4.7		-4.5		
6	CM	2130	379.5	407.0	-10.7	-5.8	4.5	7.9	
6	DOCMS	2130	379.5		4.1		-6.7		

(Table 6) "D" PINGER POSITION DATA

CURRENT PROFILE #	MOORING	TIME (Z)	"A" PINGER DEPTH (m)		"A" PINGER X EXCURSION (m)		"A" PINGER Y EXCURSION (m)		COMMENTS
			COMP.	RANGE	COMP.	RANGE	COMP.	RANGE	
					E. components pos.		N. components pos.		
0			1003.9	1036.6	0	0	0	0	ANCHOR COORDINATES X=-7186 Y=17532 DATUM HS3-4
1	CM	0000	1003.9	1040.5	1.0	-1.2	2.8	-2.4	CASE 1
1	CM	0000	1003.9		0.7		2.5		CASE 2
1	DOCMS	0000	1003.9		-0.9		2.5		
2	CM	2030	1004.5	1036.6	26.2	4.0	7.3	7.9	CASE 1
2	CM	2030	1004.6		28.5		10.8		CASE 2
2	DOCMS	2030	1003.9		1.2		-0.7		
3	CM	0130	1004.0	1028.6	-0.4	5.2	5.9	-5.8	CASE 1
3	CM	0130	1004.0		0.2		6.0		CASE 2
3	DOCMS	0130	1003.9		-5.0		-1.2		
4	CM	2330	1003.9	1038.1	3.4	-0.3	4.7	0.6	CASE 1
4	CM	2330	1003.9		2.9		4.5		CASE 2
4	DOCMS	2330	1003.9		0.5		0.8		
5	CM	0200	1003.9	1040.5	-2.9	2.1	1.7	-5.8	
5	DOCMS	0200	1003.9		-4.4		-3.5		
6	CM	2130	1003.9	1040.8	-4.8	2.1	4.3	1.8	
6	DOCMS	2130	1003.9		2.4		-4.0		

(Table 7) "A" PINGER POSITION DATA

CURRENT PROFILE #	MOORING	TIME (Z)	"B" PINGER DEPTH (m)		"B" PINGER X EXCURSION (m)		"B" PINGER Y EXCURSION (m)		COMMENTS
			COMP	RANGE	COMP	RANGE	COMP	RANGE	
					E. Components Pos.		N. Components Pos.		
0			1401.3	1432	0	0	0	0	ANCHOR COORDINATES X=-7186 Y=17532 DATUM HS3-4
1	CM	0000	1401.3	1432	-0.9	0.3	1.5	-1.5	CASE 1
1	CM	0000	1401.3		-1.0		1.3		CASE 2
1	DOCMS	0000	1401.3		-0.6		1.2		
2	CM	2030	1401.6	1443	13.2	0.6	3.7	3.3	CASE 1
2	CM	2030	1401.7		14.2		5.4		CASE 2
2	DOCMS	2030	1401.3		0.6		-0.3		
3	CM	0130	1401.4	1437.5	-2.2	0.6	2.3	-4.3	CASE 1
3	CM	0130	1401.4		-1.8		2.3		CASE 2
3	DOCMS	0130	1401.3		-3.2		-0.7		
4	CM	2330	1401.3	1438.4	0.8	0	2.6	-0.6	CASE 1
4	CM	2330	1401.3		0.6		2.5		CASE 2
4	DOCMS	2330	1401.3		0.1		0.4		
5	CM	0200	1401.3	1440.5	-2.8	1.8	0.0	-3.4	
5	DOCMS	0200	1401.4		-3.1		-1.5		
6	CM	2130	1401.3	1444.5	-1.7	1.8	2.5	1.5	
6	DOCMS	2130	1401.3		1.1		-1.8		

(Table 8) "B" PINGER POSITION DATA

table shows the computed depth of each pinger assuming zero current and the minimum depth as measured by the range. (Minimum depth is assumed to be zero current.) The anchor coordinates are shown in the right-hand column. These coordinates are expressed in feet, from a reference datum point which is hydrophone HS3-4 at position 22°07'21.29" north latitude, 59°55'20.20" west longitude. Positive values of X and Y are east and north respectively of the origin. Negative values are west and south.

4.1 Launch Trajectory - Tracking of the four pingers during the anchor launch permitted a detailed description of the four mooring points in X, Y and Z coordinates. Figure 24 shows the X and Y (west and north) coordinates in feet from a central range datum point (hydrophone HS3-4) of the four pingers beginning one minute before anchor launch (1806 Z). The vessel's position at time of launch (1807 Z) is shown as a triangle in the upper left hand corner. Just prior to launch the pingers were stretched out behind the vessel near the surface in the order B, A, D, C beginning at the vessel. At launch it can be seen that pingers B and A proceeded towards the vessel as the anchor pulled the complete mooring down and over in what is commonly referred to as the water sheave effect. Pingers C and D did not experience this motion but rather were pulled in a reasonably straight line to their ultimate position over the anchor Figure 25 is a more detailed section of Pinger B during this anchor launch operation. The water sheave effect can be clearly seen in this figure. The depth of each pinger as a function of time during the launch sequence is shown in Figure 26.

4.2 Recovery Trajectory - Continuous tracking of the four pingers provided an opportunity to observe the ascent trajectories after firing the acoustic anchor release. Figure 27 depicts the ascent of each pinger beginning with anchor release. While the upper two pingers (C and D)

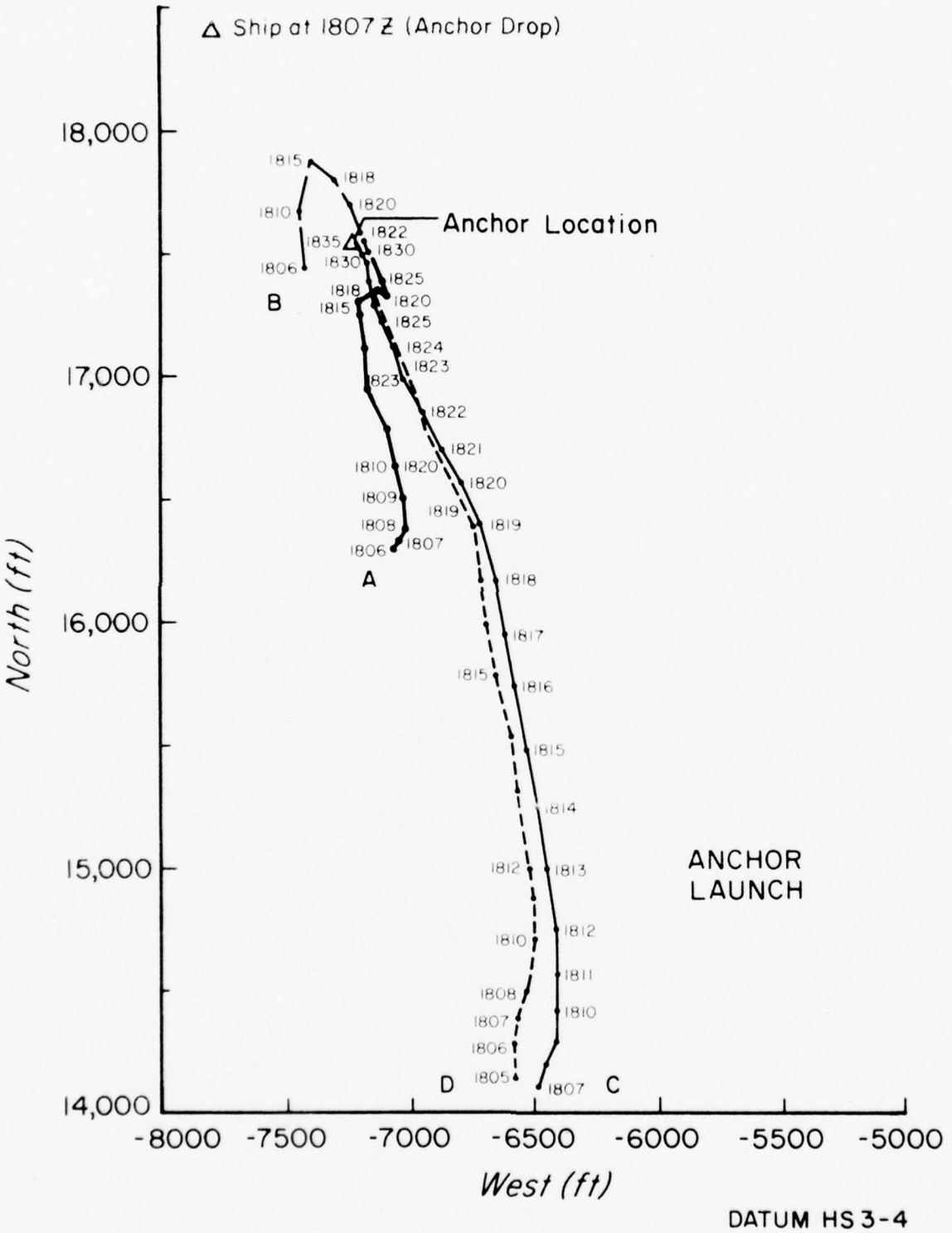


Figure 24 Pinger Motion During Anchor Descent

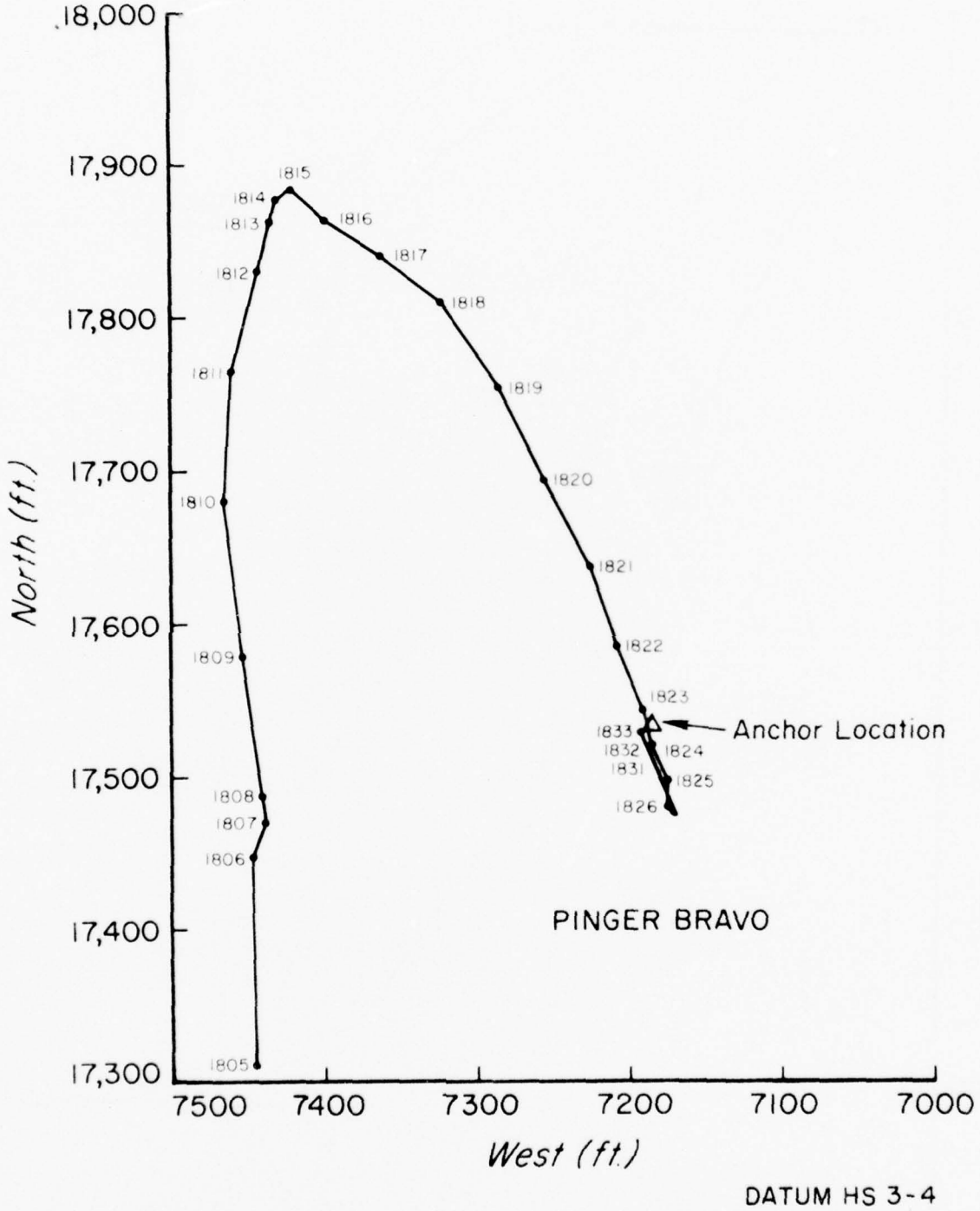


Figure 25 Pinger "B" During Anchor Descent

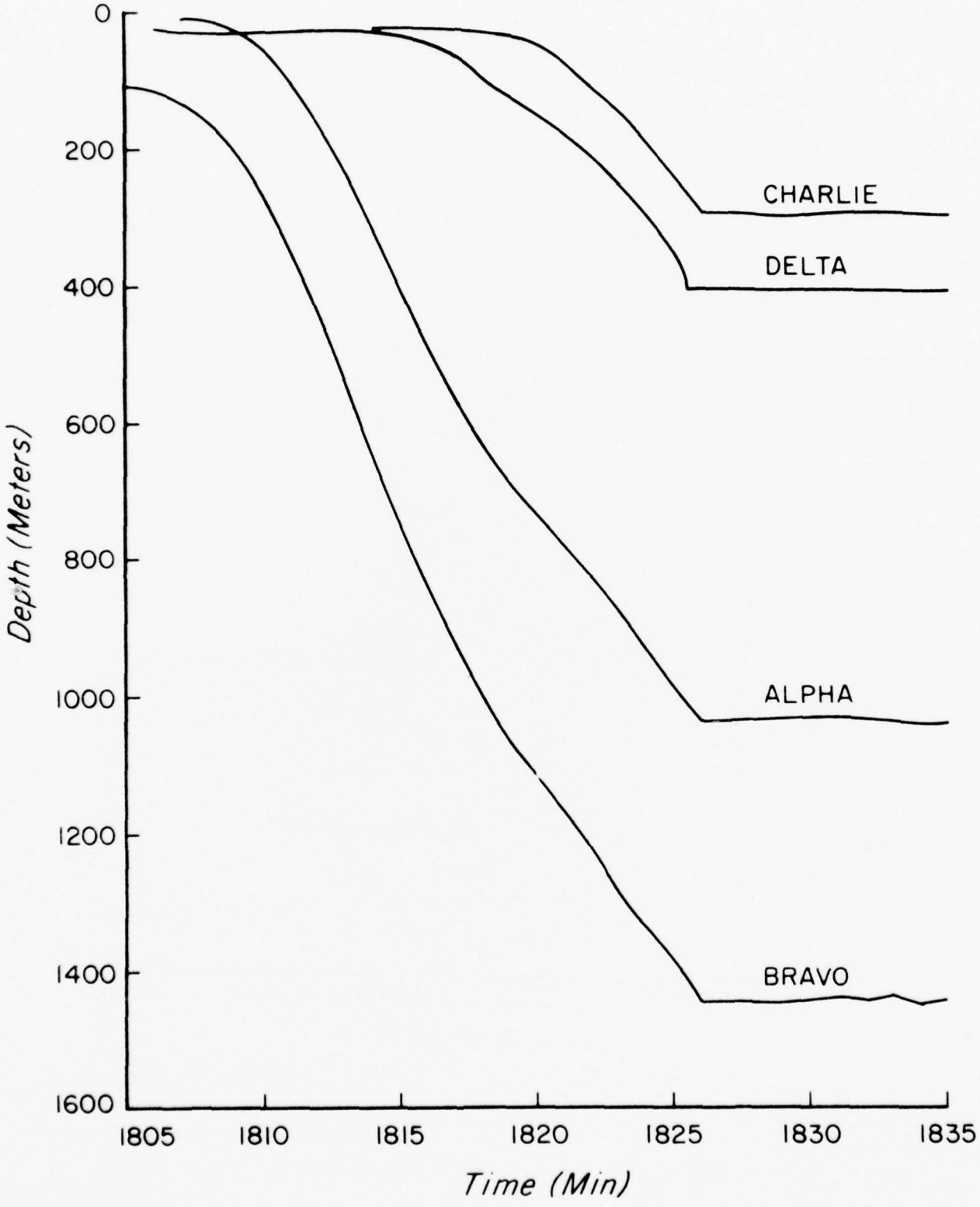


Figure 26 Pinger Descents

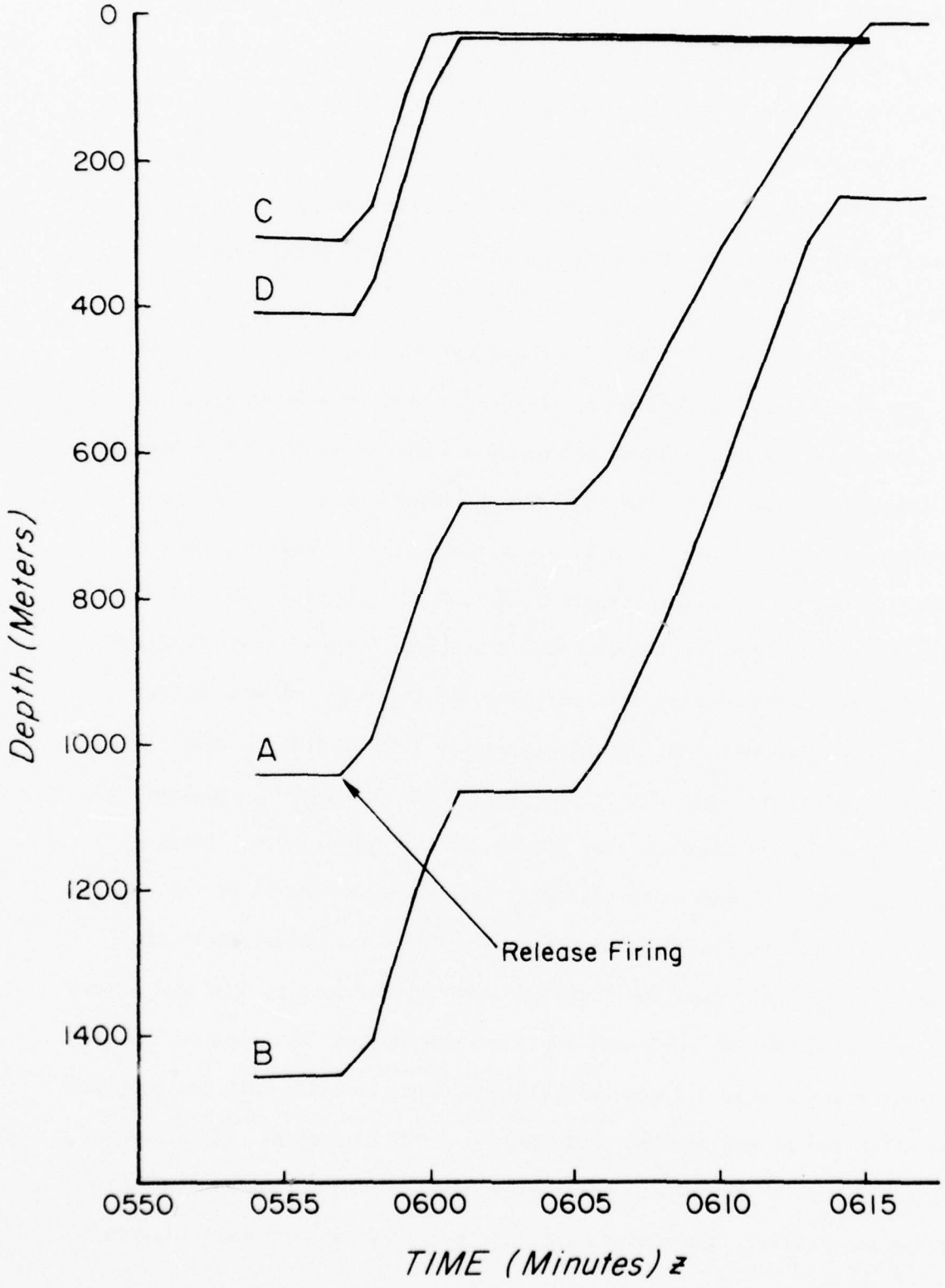


Figure 27 Pinger Ascents

proceed immediately to the surface the bottom two ascend, stop and then ascend again. This effect is due to the back-up recovery flotation. Upon anchor release the whole mooring travels vertically until the top sphere reaches the surface. At this time both pingers A and B are hanging at their respective depths less the distance the sphere traveled to the surface (380 m). In the meantime the back-up recovery system is still ascending and when it overtakes the pingers starts to bring them to the surface.

4.3 Mooring Dip - Table 9 shows the mooring dip as computed and measured at the two T/P recorders. The T/P's were located adjacent to pingers D and B whose indicated values were adjusted to the T/P locations. The depth determination of the B pinger by acoustic means is the least reliable measurement in this table because of the unfavorable geometry. Looking at the zero current situation we find the computer value of the T/P depth to be 376 meters while the T/P recorder indicates 390.8 meters and the pinger acoustically derived value 401.2 meters. A reasonable assumption can be made that because there has been no refined sound velocity correction applied to the data that the T/P value is probably the most accurate measurement of that pinger depth which we have. Thus a discrepancy of 14.8 meters is present. This is less than 1% of the depth and can well be attributed to wire measurement error, which can be that large. On the other hand the computed depth of the deep or B pinger agrees very well with the T/P indicated depth suggesting that the mooring was set in a water depth only 3.2 meters shallower than planned. Both the computer prediction and pinger depths, while having a small constant offset, most probably due to a wire measurement error, vary not more than a meter from profile to profile. The obvious conclusion is that an extremely effective

CURRENT PROFILE #	MOORING	TIME (Z)	T/P DEPTH (m)			T/P DEPTH (m)			COMMENTS
			COMP	T/P	"D" PINGER	COMP	T/P	"B" PINGER	
0			376.0	390.8	401.2	1396.9	1393.7	1427.6	NO CURRENT
1	CM	0000	376.0			1396.9			CASE 1
1	CM	0000	376.0	391.3	403.6	1396.9	1393.7	1427.6	CASE 2
1	DOCMS	0000	376.0			1396.9			
2	CM	2030	376.8			1397.2			CASE 1
2	CM	2030	377.0	391.4	401.2	1397.3	1393.7	1438.6	CASE 2
2	DOCMS	2030	376.0			1396.9			
3	CM	0130	376.0			1396.9			CASE 1
3	CM	0130	376.0	391.3	403.9	1396.9	1393.7	1433.1	CASE 2
3	DOCMS	0130	376.0			1396.9			
4	CM	2330	376.0			1396.9			CASE 1
4	CM	2330	376.0	391.3	405.1	1396.9	1393.7	1434	CASE 2
4	DOCMS	2330	376.0			1396.9			
5	CM	0200	376.0	391.3	403.3	1396.9	1393.7	1436.1	
5	DOCMS	0200	376.0			1396.9			
6	CM	2130	376.0	391.0	403.6	1396.9	1393.7	1440.1	
6	DOCMS	2130	376.0			1396.9			

(Table 9) COMPUTER, T/P AND PINGER COMPARISON, VERTICAL EXCURSION

mooring was indeed designed and set. Perhaps for the purposes of this validation, a less effective "softer" mooring would have been better. We can state, however, that during the six observation times chosen there were no vertical excursions greater than one meter.

4.4 Horizontal Excursion - Referring to Tables 5 - 8 the X and Y excursions of each pinger in meters from an assumed anchor position is given for the six different observation times. The predicted values from the computer program using current profiles obtained from the current meter mooring and the DOCMS mooring separately are compared with the measurements of the pinger position made by the range. Table 10 shows the average differences between computed and measured horizontal displacements of the four pingers. Separate calculations were done using current profiles obtained from a) the current meter mooring, and b) the DOCMS mooring. The smallest differences especially in the east-west direction are obtained when current information from the DOCMS mooring is used.

Figure 28 shows a plan view of the position of each pinger at each of the observation times. The inferred anchor location is also indicated.

5.0 Conclusions

The DOCMS mooring was in place and taking measurements for 12 hours 11 minutes. The quality of the measurements appears to have been excellent. On the DOCMS mooring four pingers worked continuously for the full experiment duration as did two T/P recorders and three Aanderaa current meters. The dual releases also functioned properly, so that 100% data recovery was obtained for the full time period involved. On the remote current meter mooring there also was complete data recovery except for the T/P recorder which failed to work because of a dislodged cassette. During the measurement period it can be seen from the current meter records that great variability, both in the horizontal and the vertical in the current structure was present. Little coherence was noted between the current meter mooring

and the DOCMS mooring. It was fortunate that three Aanderaa current meters were placed on the DOCMS mooring. They also permit us to recognize the spatial variability of the currents in the area. The current meter mooring two miles to the north of the DOCMS site was more heavily instrumented with five current meters distributed over the water column. Coverage on the DOCMS mooring was less with three meters, two located close to the surface and one near the bottom. Over 70% of the mooring length was not instrumented with current meters. From the results shown in this report it can be seen that better correlation between actual and computer simulation are obtained using current profiles from the DOCMS mooring. The large current variability with depth shown in the uninstrumented region of the DOCMS mooring further suggests that much better vertical instrument coverage would be required for an adequate description of the current structure with depth. Deep ocean conditions would be significantly more continuous with less shear and more vertical coherence.

The figures and tables present the actual values obtained from the instruments and from the range. Very small motions in both the vertical and horizontal were measured. Less than one meter vertical dip was observed. Horizontal displacement of the top of the mooring was generally small (five meters). On the other hand the currents during the test were small, reaching a peak of 20 cm/sec. The mooring design was similar to the recommended DOCMS mooring which is quite stiff. It would therefore not be expected to displace much under the current regime experienced.

The objectives of Task Four were met through this experiment. No changes in the DOCMS design program are suggested as a result of the experiment.

CURRENT PROFILE ORIGIN (MOORING TYPE)	DIRECTION	AVERAGE DIFFERENCE BETWEEN COMPUTED AND MEASURED EXCURSIONS (M) FOR 6 OBSERVATION TIMES			
		"C" PINGER (285 M)	"D" PINGER (379 M)	"A" PINGER (1004 M)	"B" PINGER (1401 M)
CM	EAST-WEST (X)	13.75	13.43	7.68	4.29
DOCMS	EAST-WEST (X)	4.65	4.70	3.48	1.73
CM	NORTH-SOUTH (Y)	5.68	5.82	5.33	2.85
DOCMS	NORTH-SOUTH (Y)	6.75	6.52	4.40	2.55

(Table 10) DIFFERENCES BETWEEN COMPUTED AND MEASURED HORIZONTAL EXCURSIONS

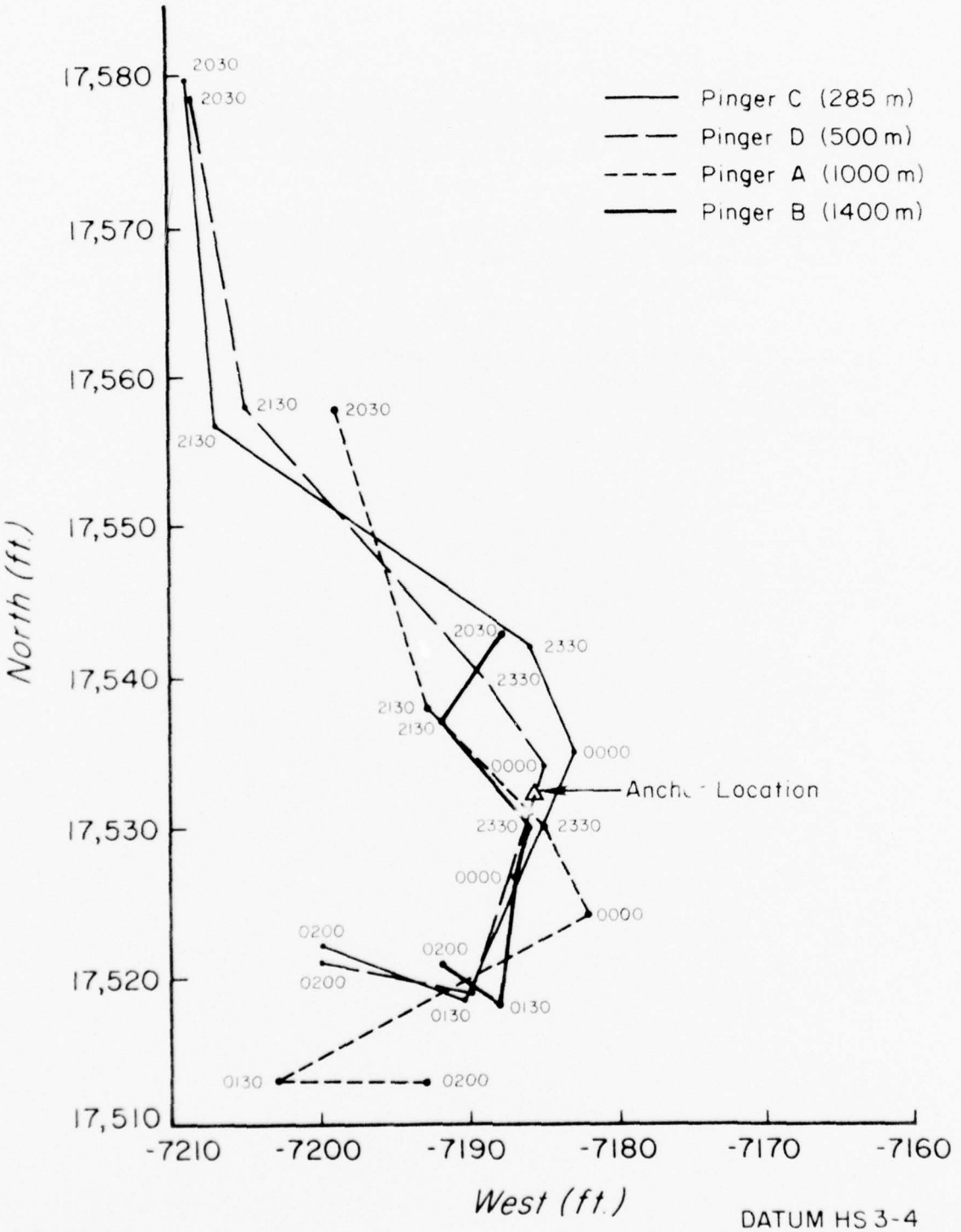


Figure 28 Pinger Locations

REFERENCES

1. Moller, D. A , "A computer program for the design and static analysis of single-point subsurface mooring systems: NOYFB", W.H.O.I. Reference No. 76-59 (Unpublished manuscript).

2. Berteaux, H. O. and Heimmiller, R. H., Jr., "Back-Up Recovery of Deep Sea Moorings", Marine Technology Society Journal, Vol. 7, No. 3, June 1973.

3. Walden, R. G. et al, "The mooring dynamics experiment -- a major study of the dynamics of buoys in the deep ocean", Proceedings of the Offshore Technology Conference, Vol. 3, Houston, Texas, 1977.

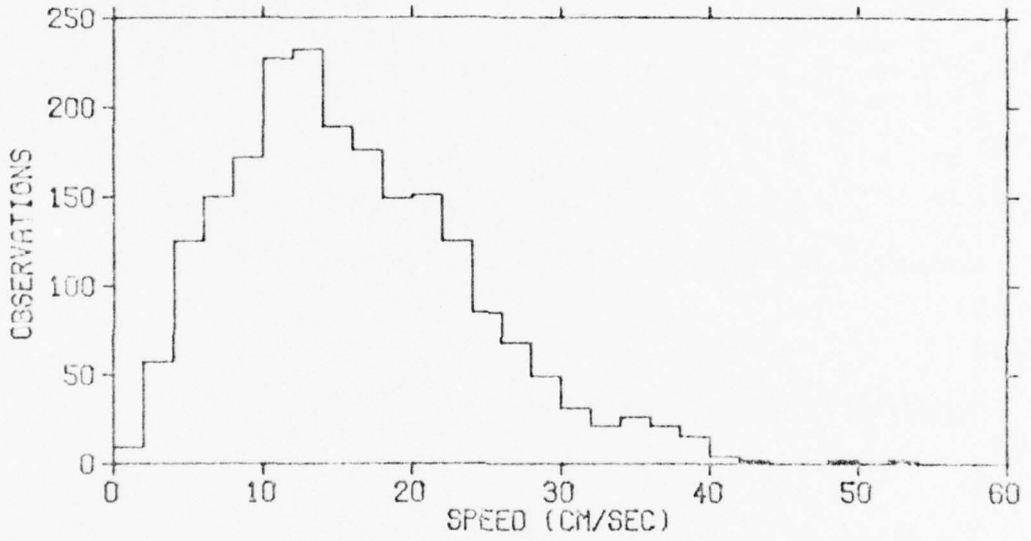
APPENDIX 1

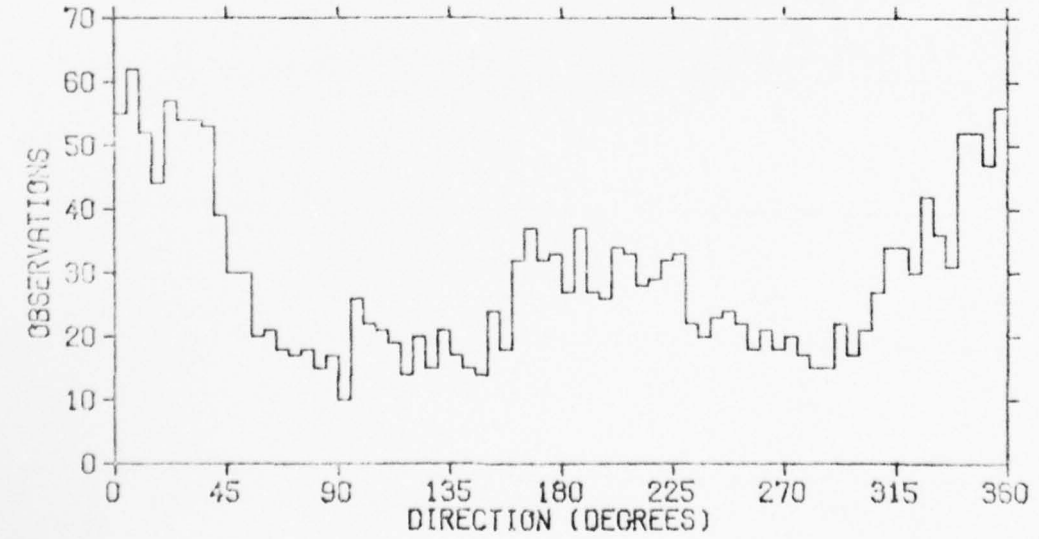
VACM Data Summaries

STATISTICS AND HISTOGRAMS OF CURRENTS AT MOORING OYN., V-0295
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 200 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, UNITS = (CM/SEC)

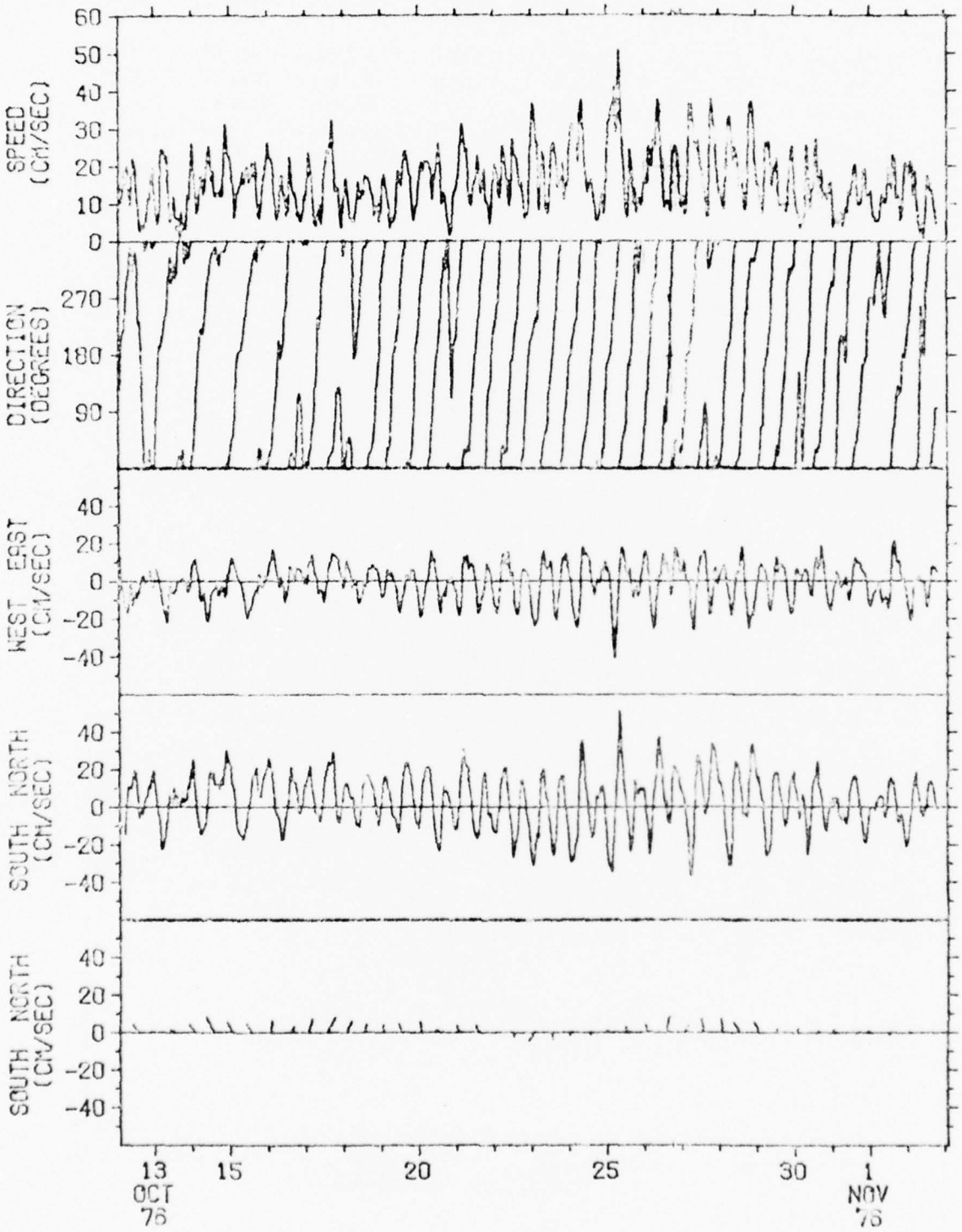
	MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
S	15.99	66.50	8.15	.749	3.530	53.37	.55
U	-1.11	102.86	10.14	-.430	3.001	28.16	-43.00
V	3.03	208.77	14.45	-.174	2.836	53.31	-38.88

S = SPEED
U = EAST-WEST COMPONENT OF VELOCITY, EAST = POSITIVE U
V = NORTH-SOUTH COMPONENT OF VELOCITY, NORTH = POSITIVE V

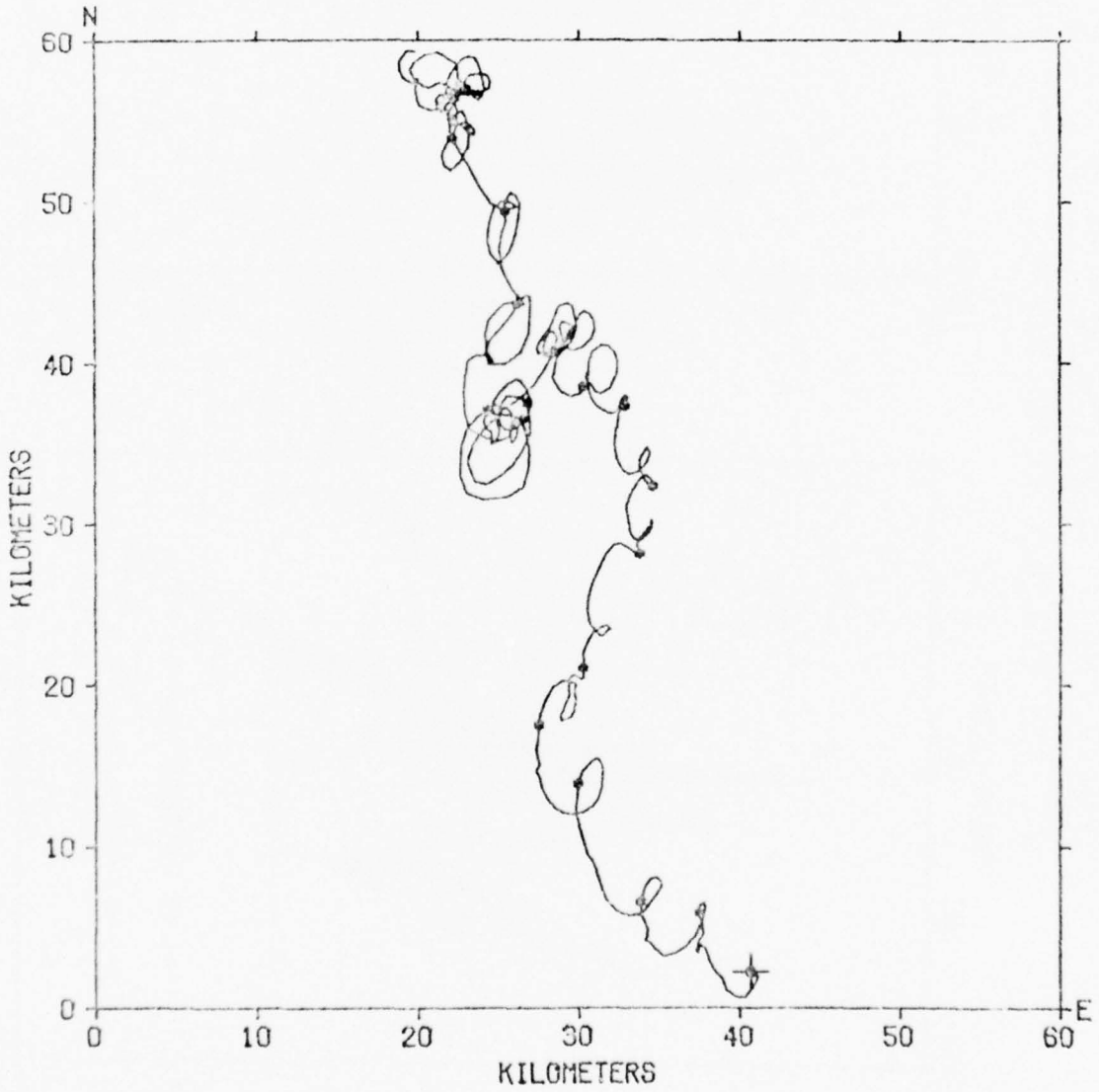




TIME SERIES OF VECTOR AVERAGED CURRENTS AT MOORING DYN., V-0295
LOCATION = LAT 22 12.2N, LONG 159 58.8W, DEPTH = 200 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
AVERAGING INTERVAL = 1.0 HOURS (4 POINTS)



PROGRESSIVE VECTOR DIAGRAM OF CURRENTS AT MOORING DYN.. V-0295
LOCATION = LAT 22 12.2N, LONG 159 56.0W, DEPTH = 200 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
¤ EVERY 1.0 DAYS BEGINNING AT 0000 13 OCT 76



U, V AND ROTORY SPECTRA OF CURRENTS AT MOORING DYN.. V-0295
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 200 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
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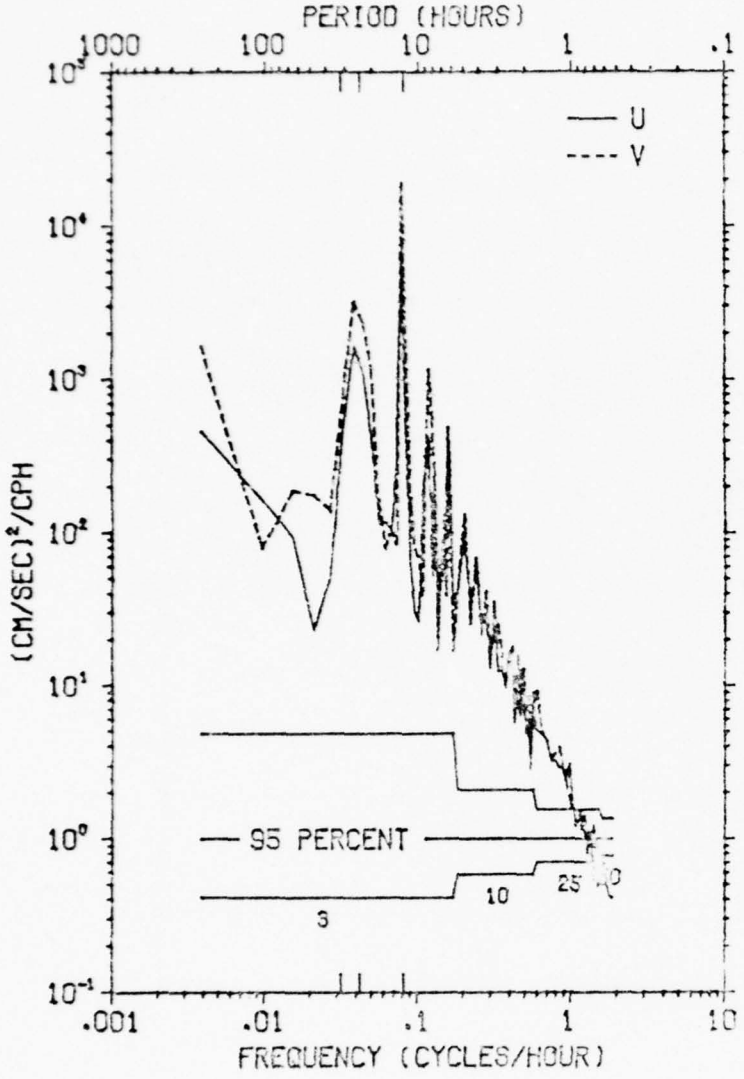

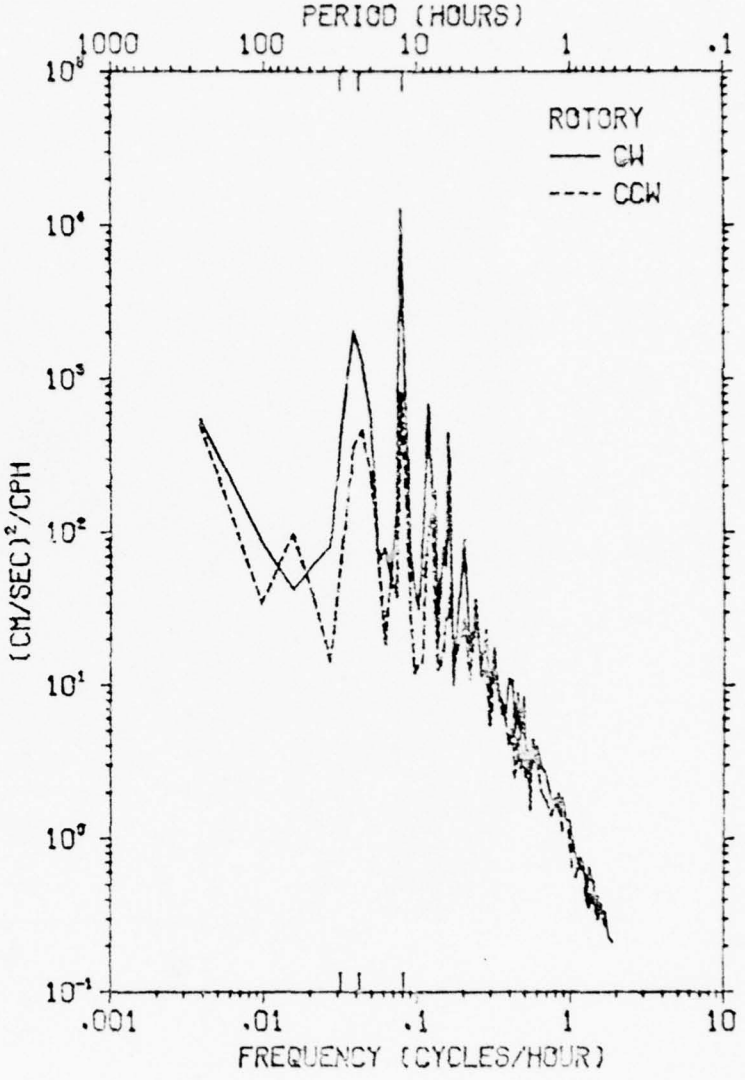

KINETIC ENERGY SPECTRUM OF CURRENTS AT MOORING DYN., V-0295
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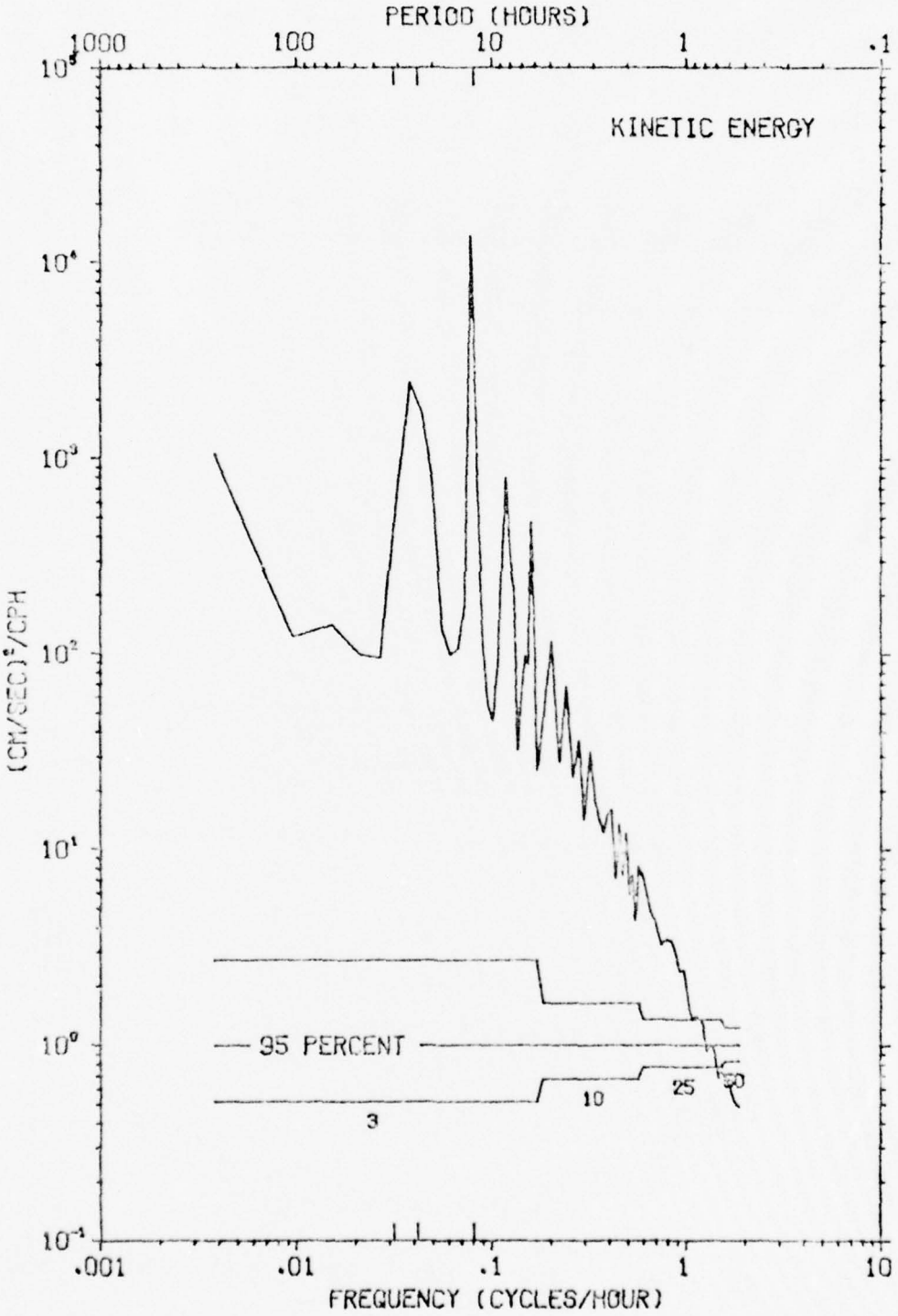
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, SMOOTHING - DANIELL WINDOW



STATISTICS AND HISTOGRAMS OF CURRENTS AT MOORING DYN., V-0293
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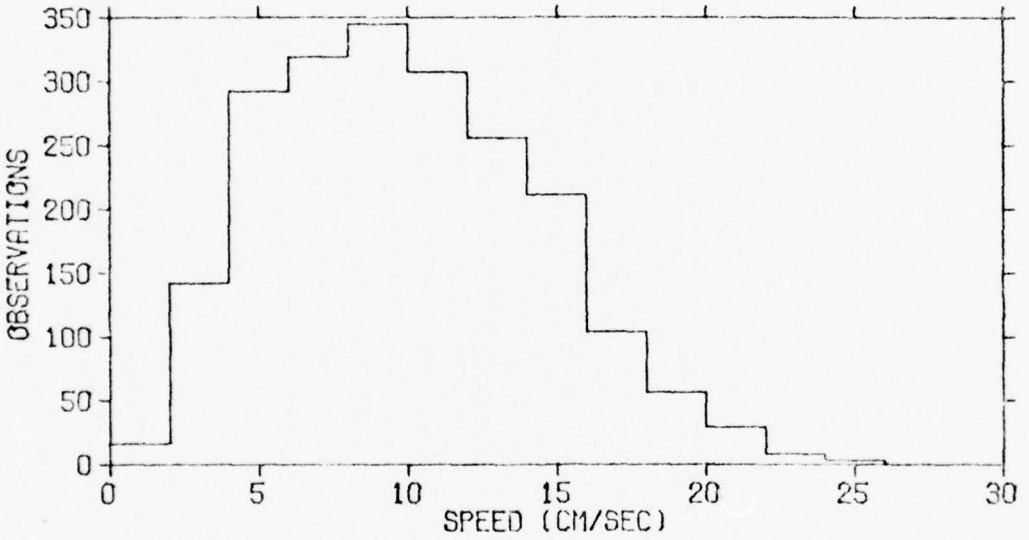
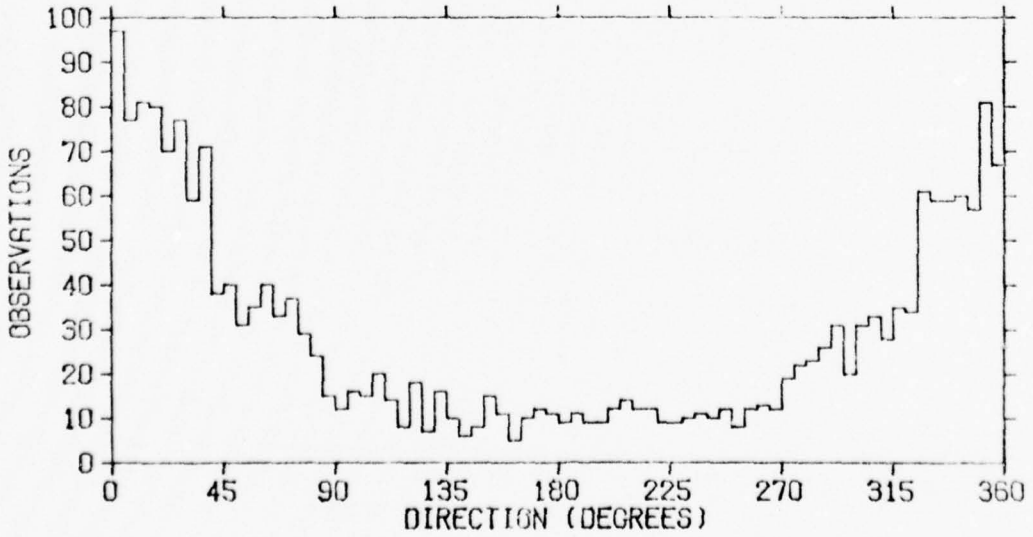
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, UNITS = (CM/SEC)

	MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
S	9.97	19.80	4.45	.414	2.661	26.00	.60
U	.94	40.93	6.40	.208	2.938	21.73	-17.33
V	5.80	43.86	6.62	-.329	2.808	24.46	-16.19

S = SPEED
U = EAST-WEST COMPONENT OF VELOCITY, EAST = POSITIVE U
V = NORTH-SOUTH COMPONENT OF VELOCITY, NORTH = POSITIVE V





TIME SERIES OF VECTOR AVERAGED CURRENTS AT MOORING DYN., V-0293
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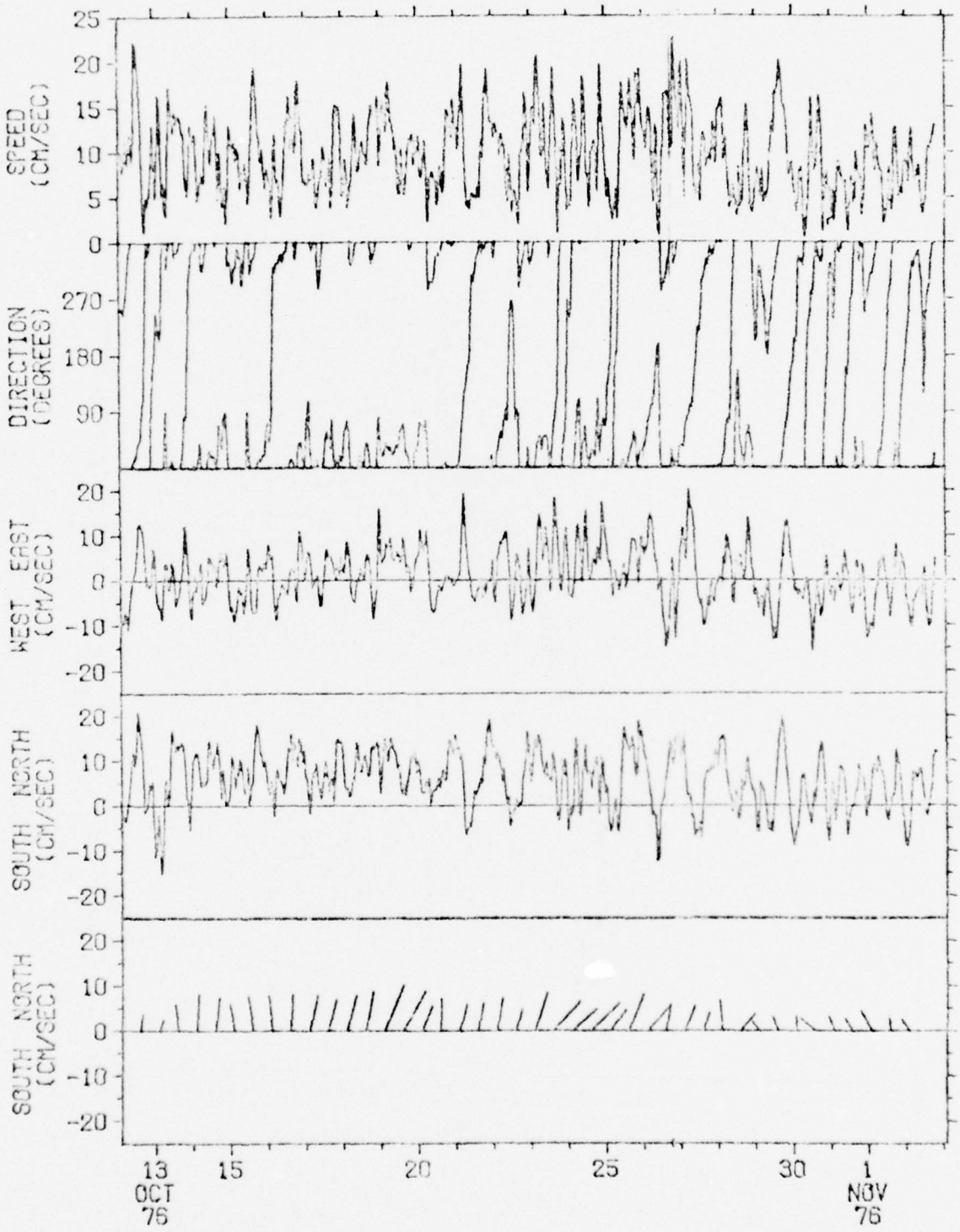

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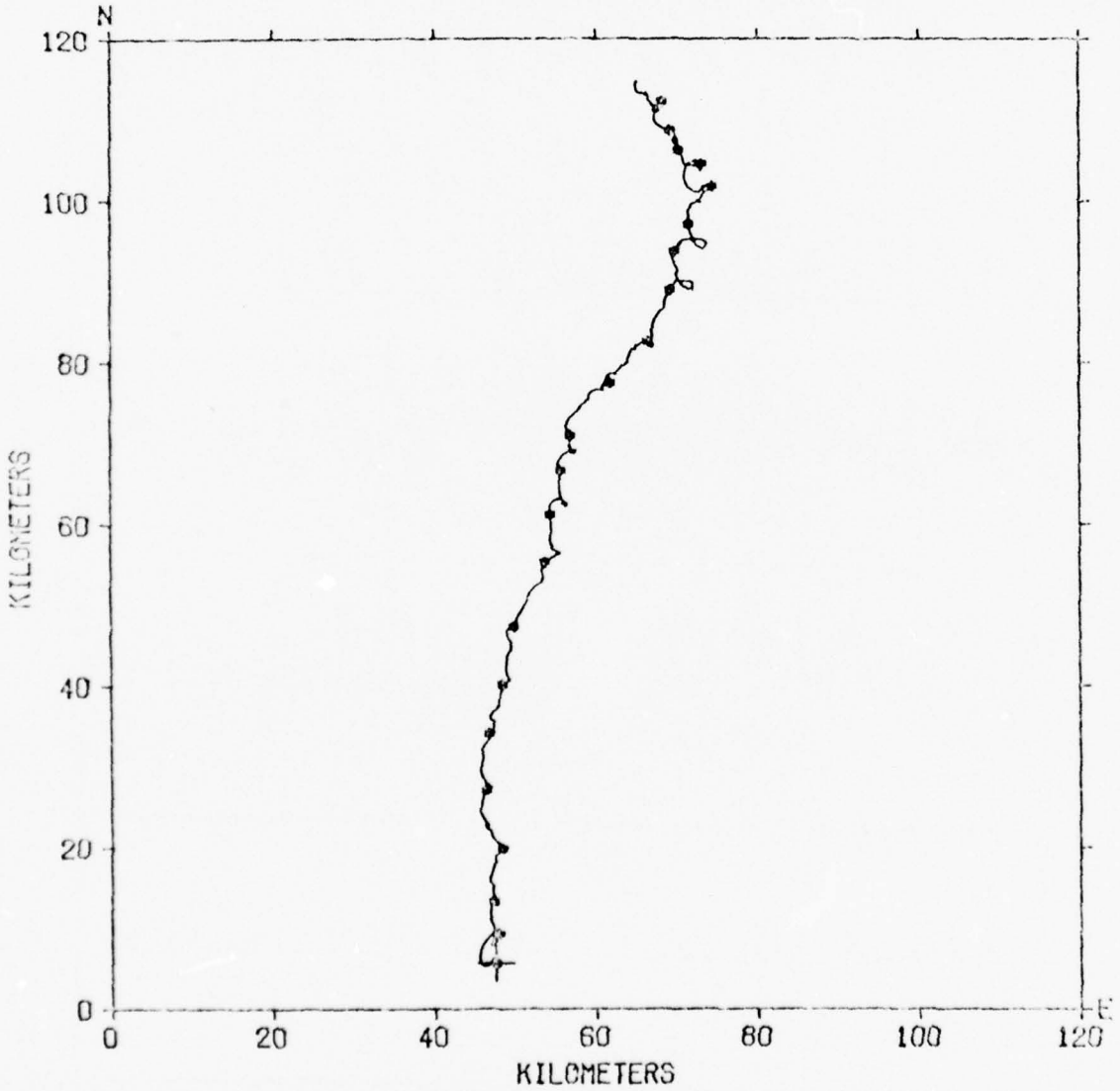
* EVERY 1.0 DAYS BEGINNING AT 0000 13 OCT 76



U, V AND ROTORY SPECTRA OF CURRENTS AT MOORING DYN., V-0293
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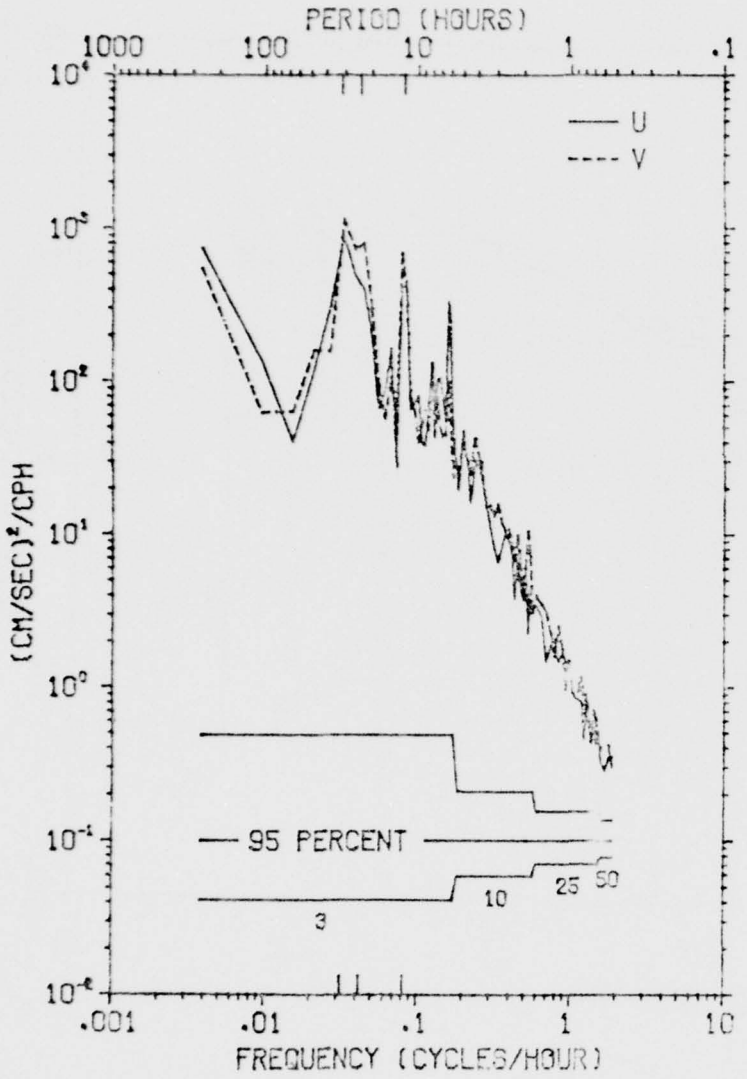

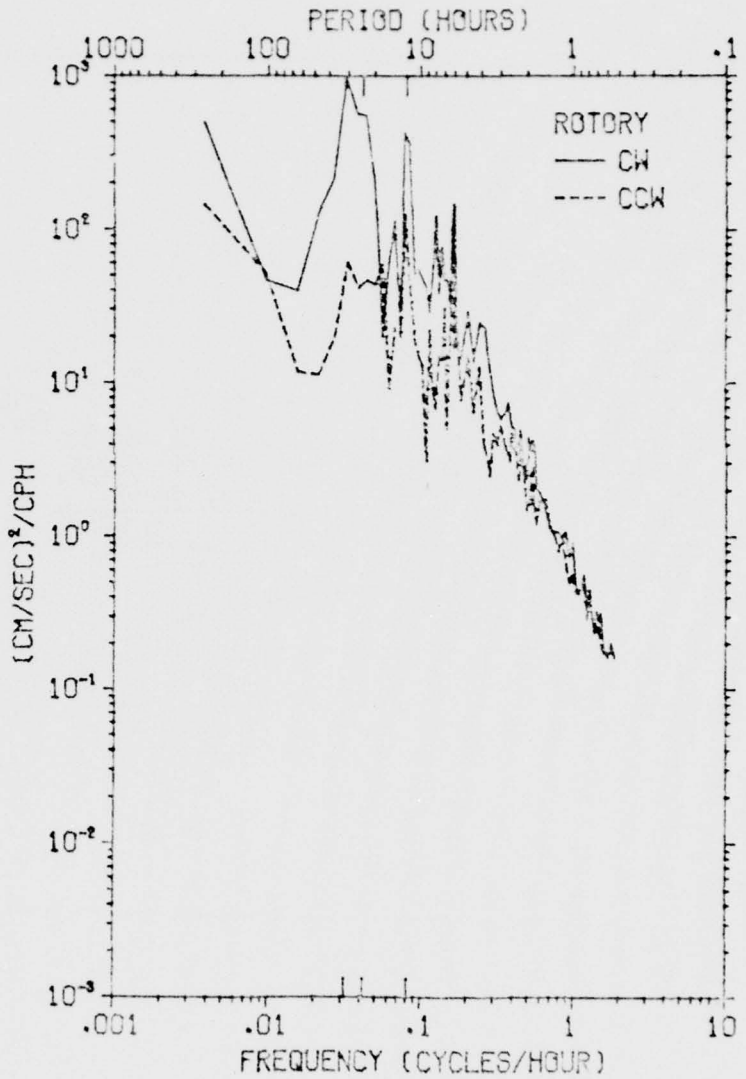

KINETIC ENERGY SPECTRUM OF CURRENTS AT MOORING DYN., V-0293
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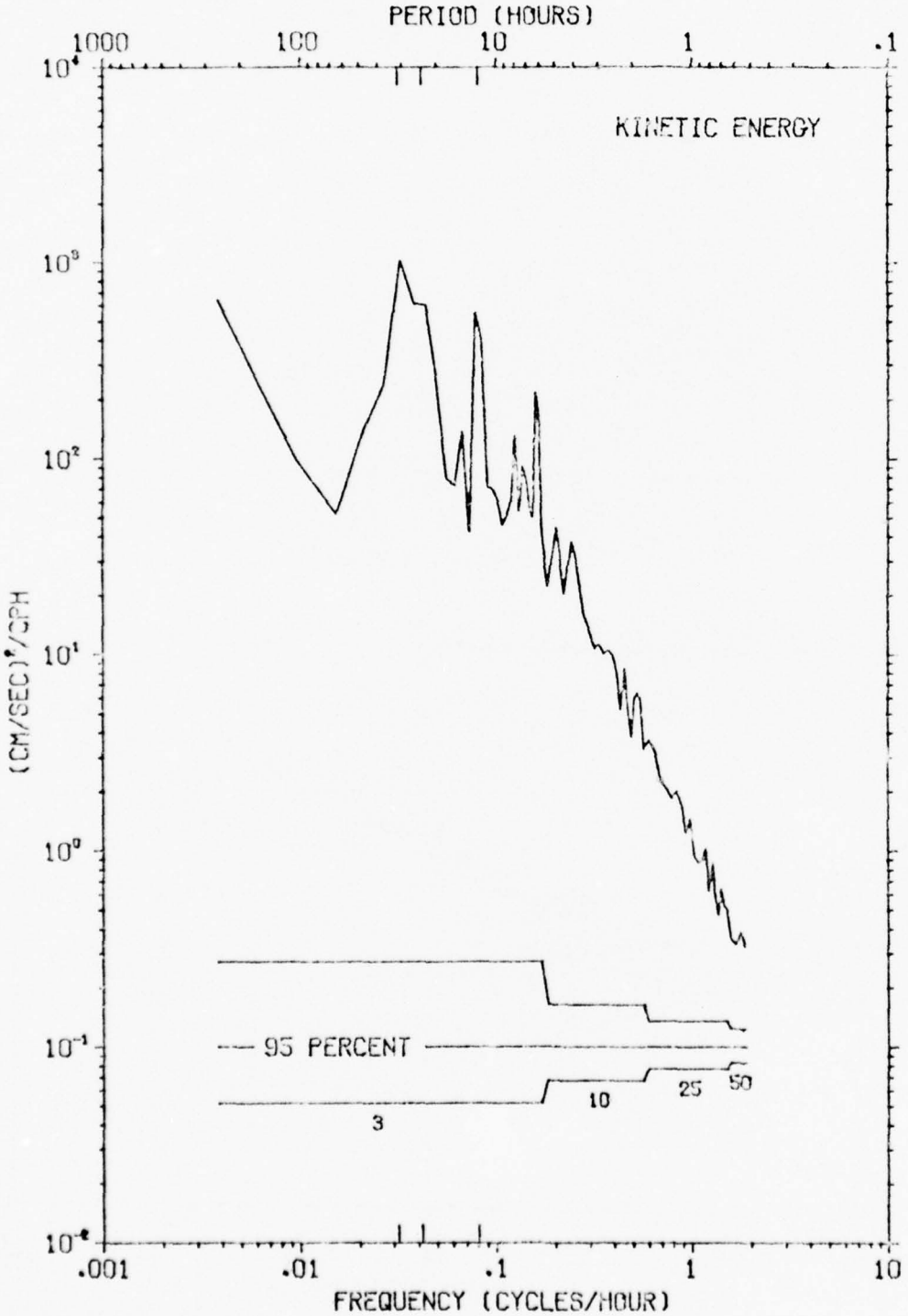

STATISTICS AND HISTOGRAMS OF CURRENTS AT MOORING DYN., V-0264
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 750 METERS
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N = 2088, DT = 15.00 MINUTES, UNITS = (CM/SEC)

	MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
S	6.90	10.00	3.16	.829	3.675	20.78	.13
U	-.78	28.67	5.35	.135	2.612	13.84	-20.73
V	.38	28.17	5.31	.125	2.866	18.17	-15.64

S = SPEED
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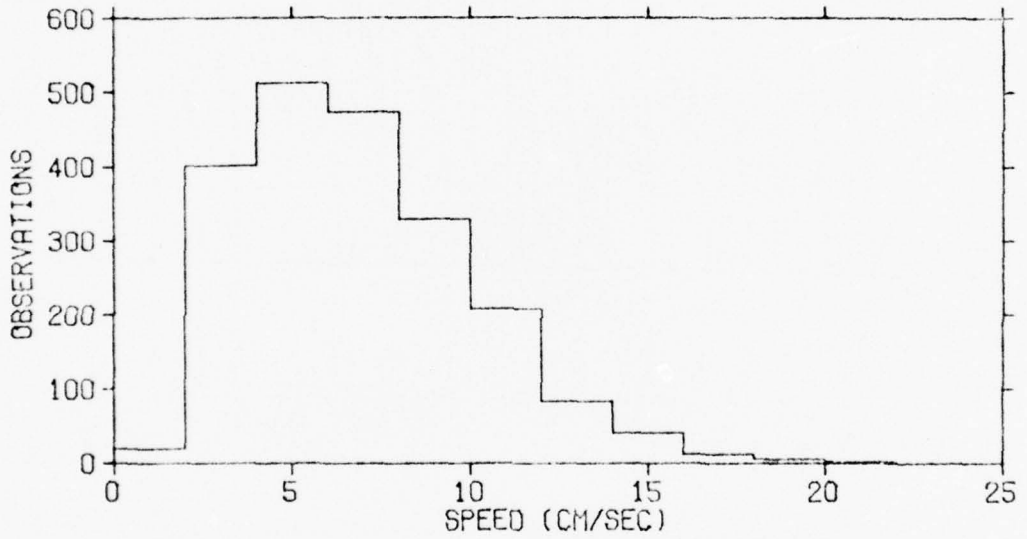

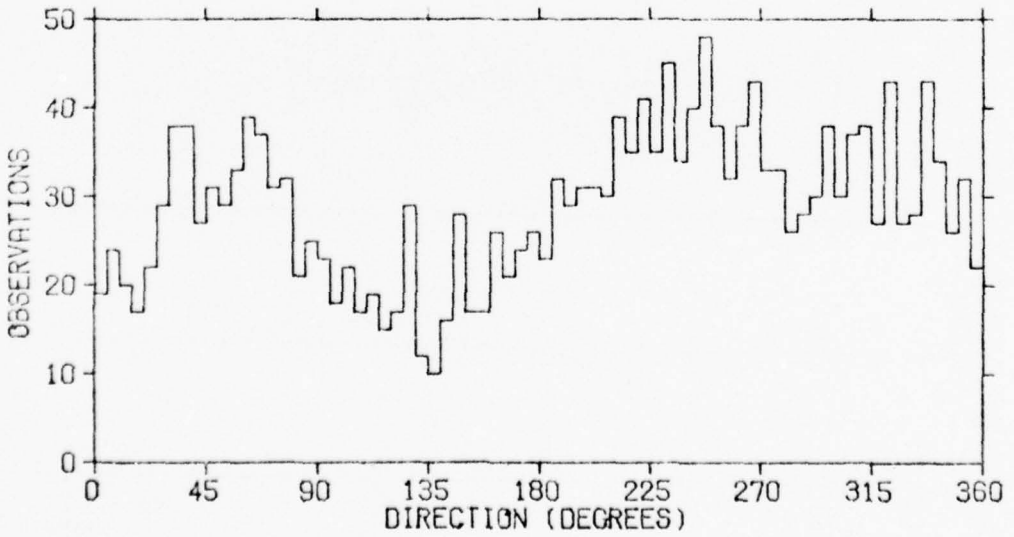

TIME SERIES OF VECTOR AVERAGED CURRENTS AT MOORING DYN., V-0264
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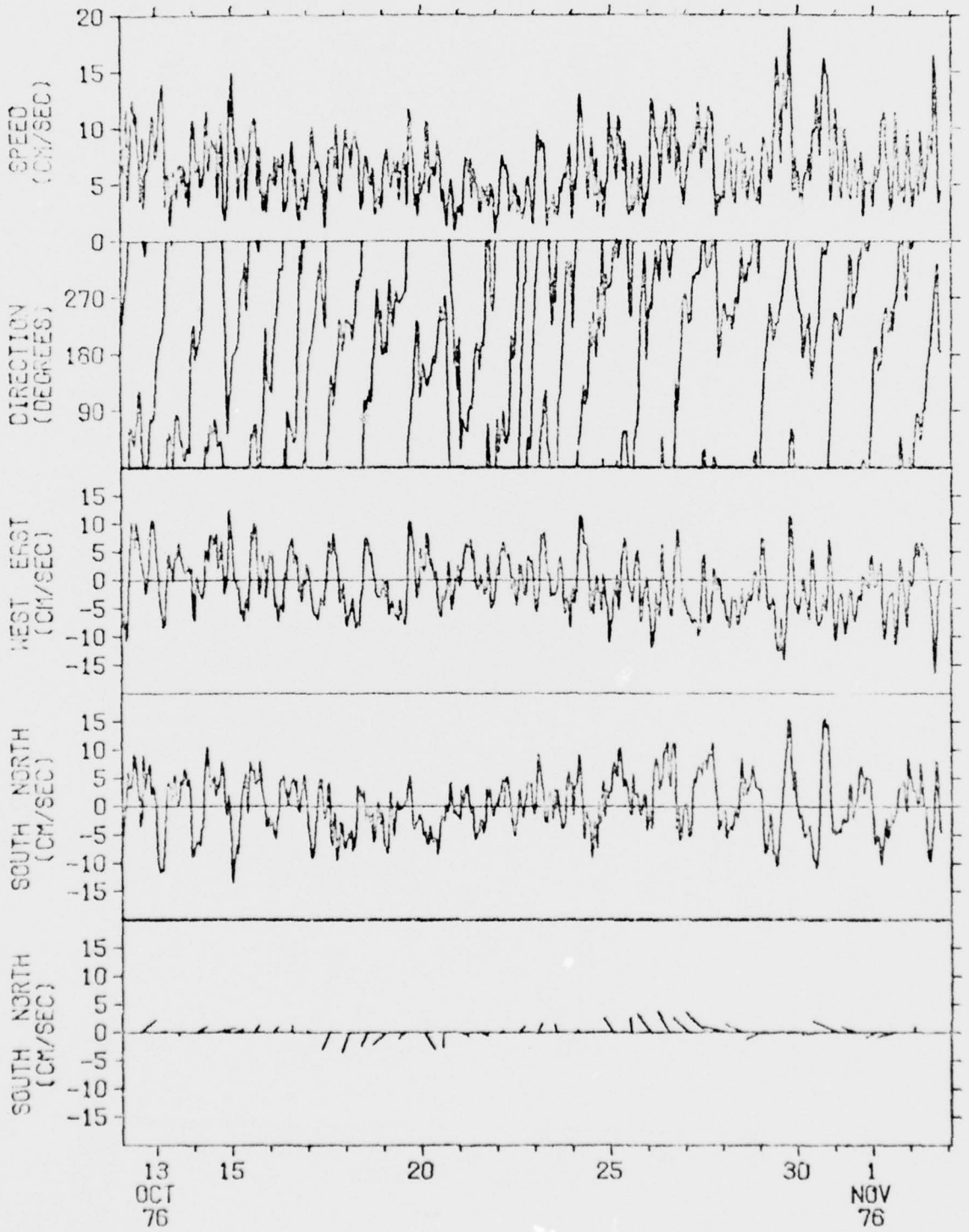
AVERAGING INTERVAL = 1.0 HOURS (4 POINTS)



PROGRESSIVE VECTOR DIAGRAM OF CURRENTS AT MOORING DYN., V-0264
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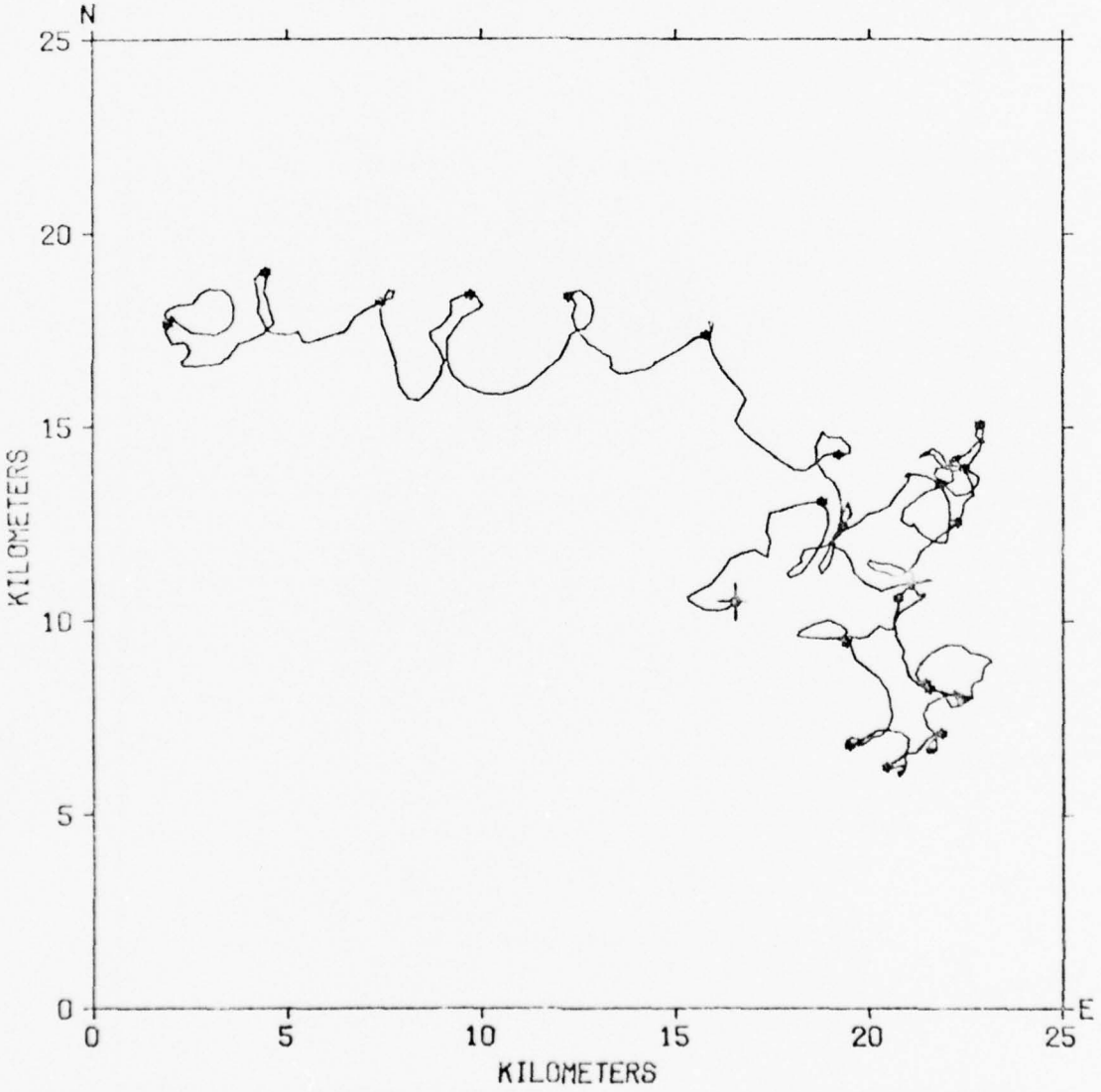
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
* EVERY 1.0 DAYS BEGINNING AT 0000 13 OCT 76



KINETIC ENERGY SPECTRUM OF CURRENTS AT MOORING DYN., V-0264
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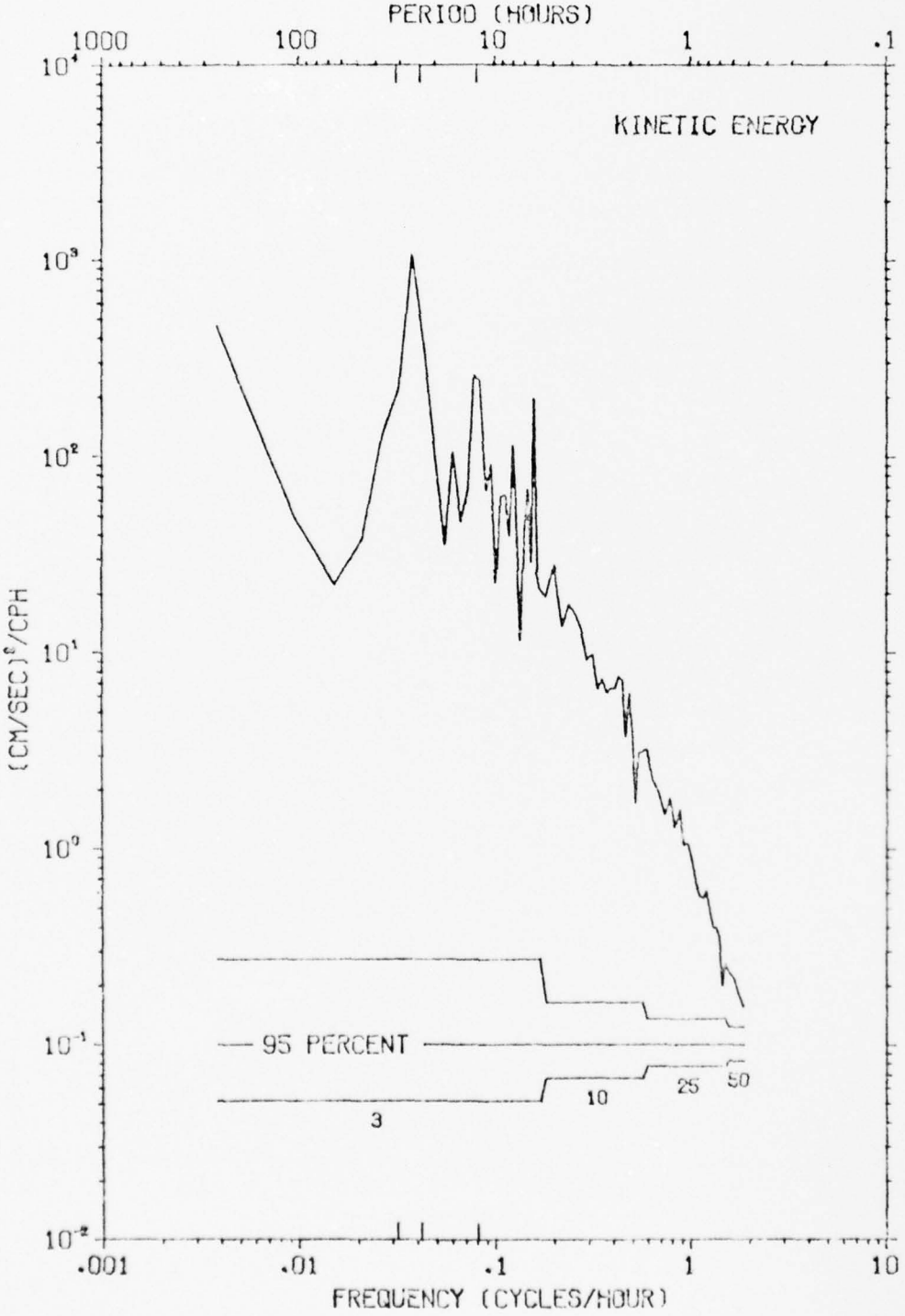
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088. DT = 15.00 MINUTES. SMOOTHING - DANIELL WINDOW



STATISTICS AND HISTOGRAMS OF CURRENTS AT MOORING DYN., V-0253
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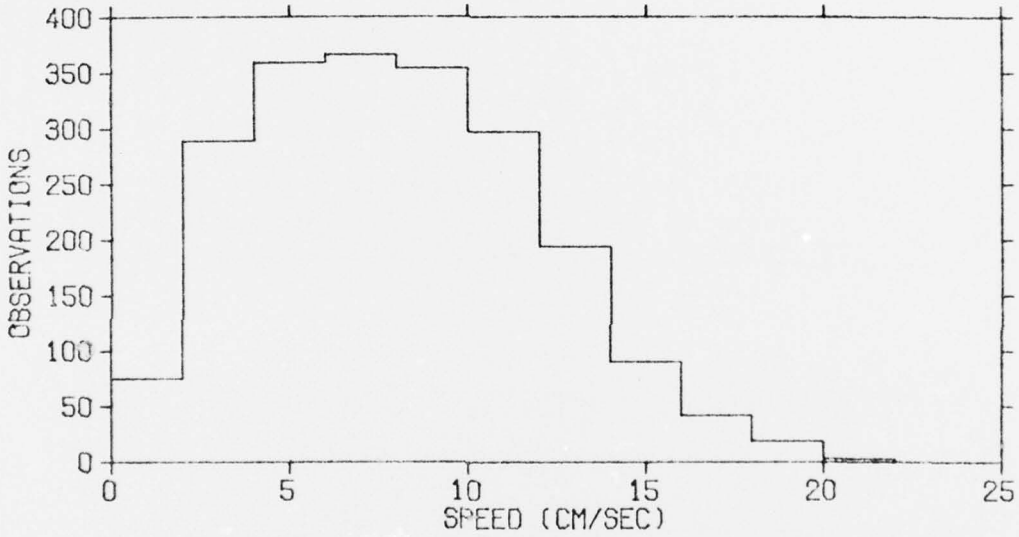
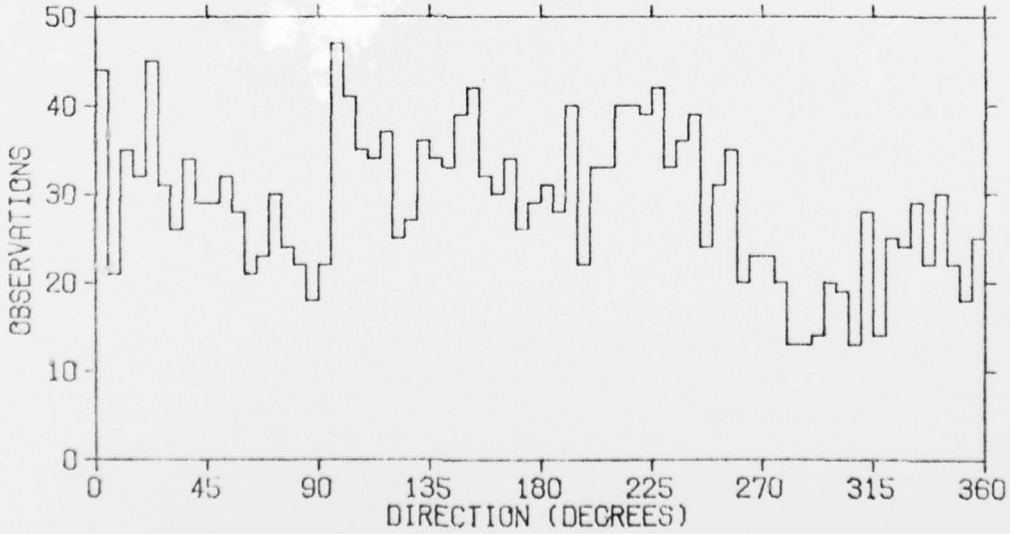
N = 2088, DT = 15.00 MINUTES, UNITS = (CM/SEC)

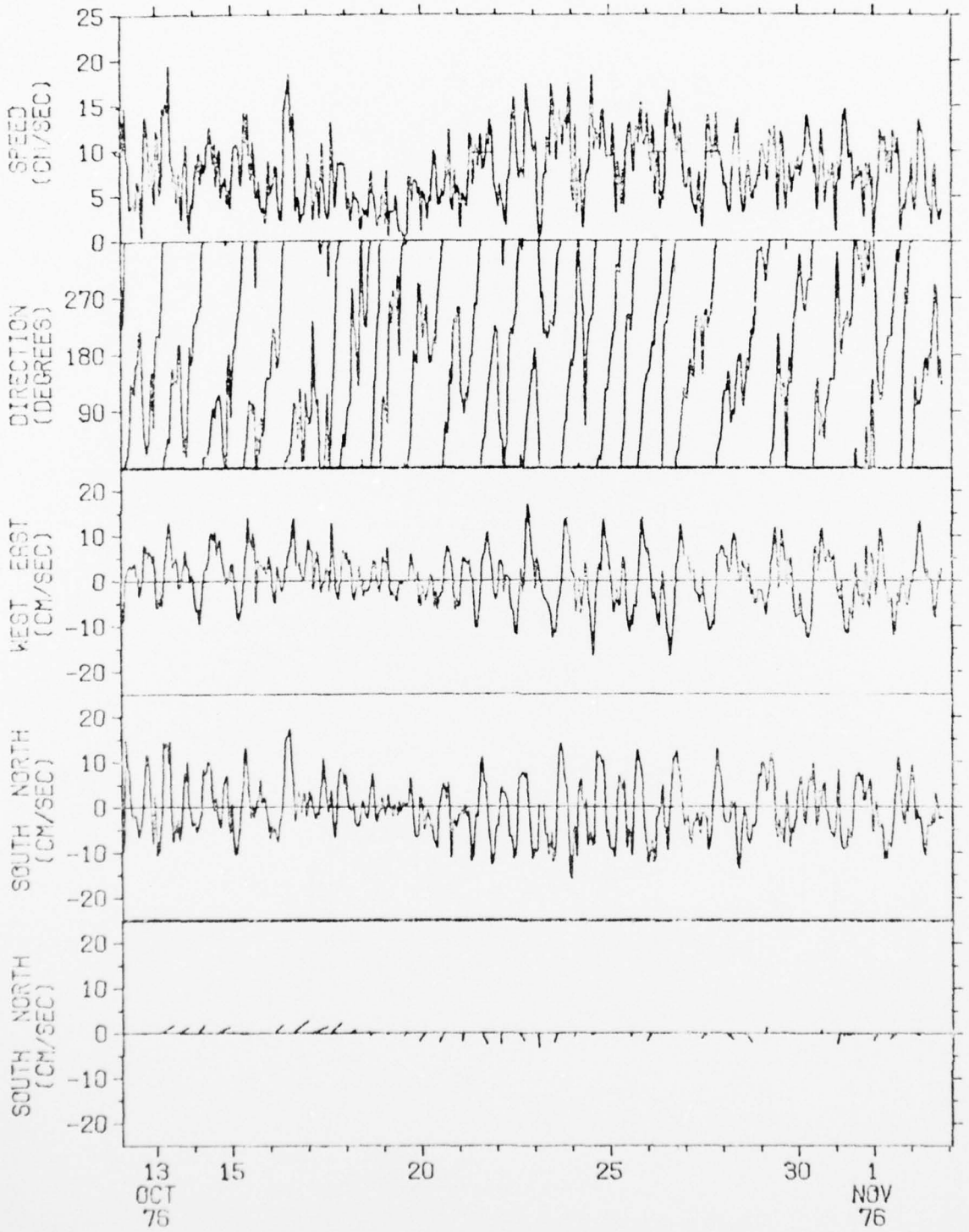
	MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
S	8.03	15.61	3.95	.390	2.729	21.46	.00
U	.44	37.26	6.10	-.065	2.759	17.73	-18.87
V	-.40	42.44	6.51	.289	2.659	20.63	-18.34

S = SPEED
U = EAST-WEST COMPONENT OF VELOCITY, EAST = POSITIVE U
V = NORTH-SOUTH COMPONENT OF VELOCITY, NORTH = POSITIVE V

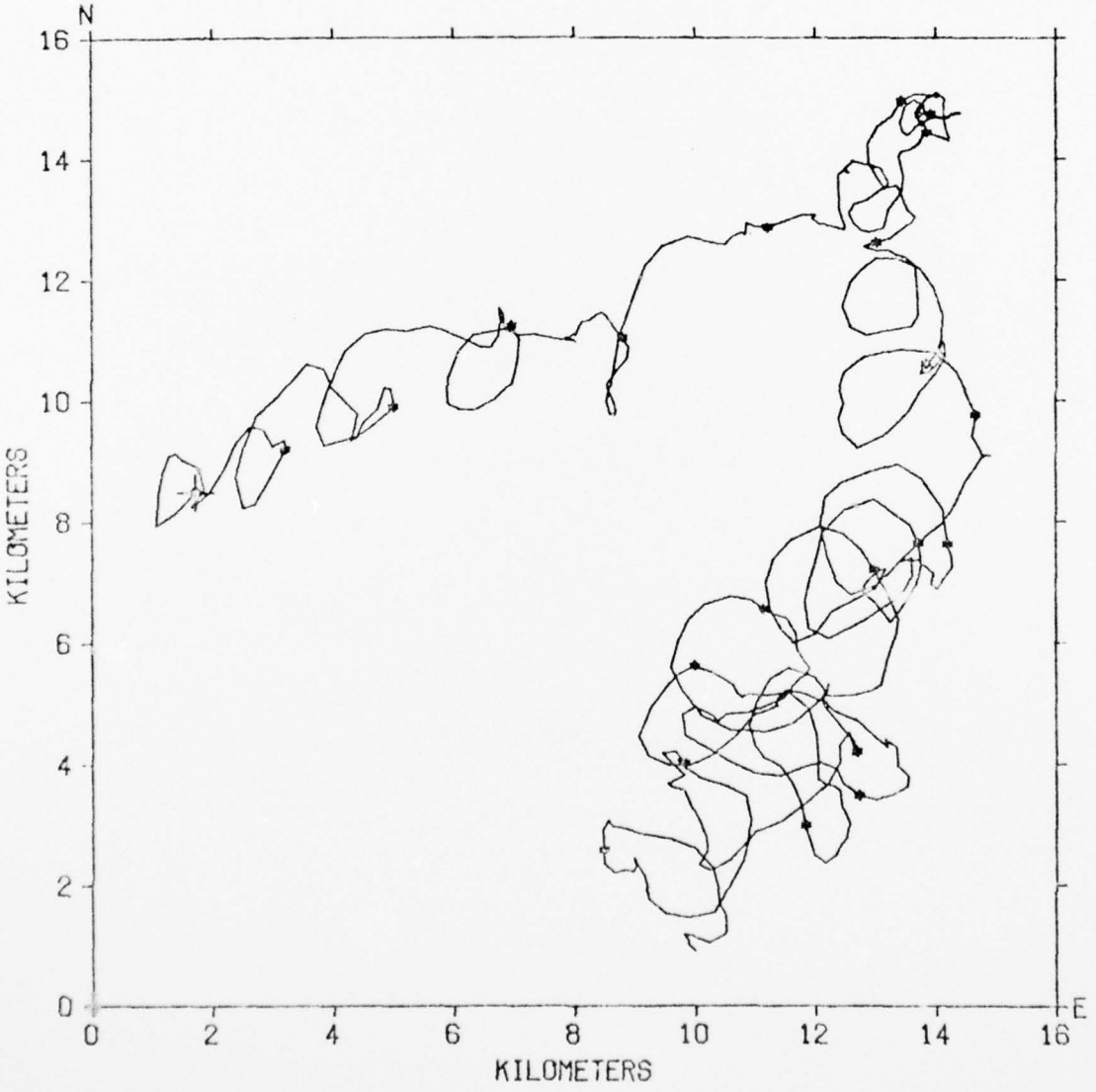




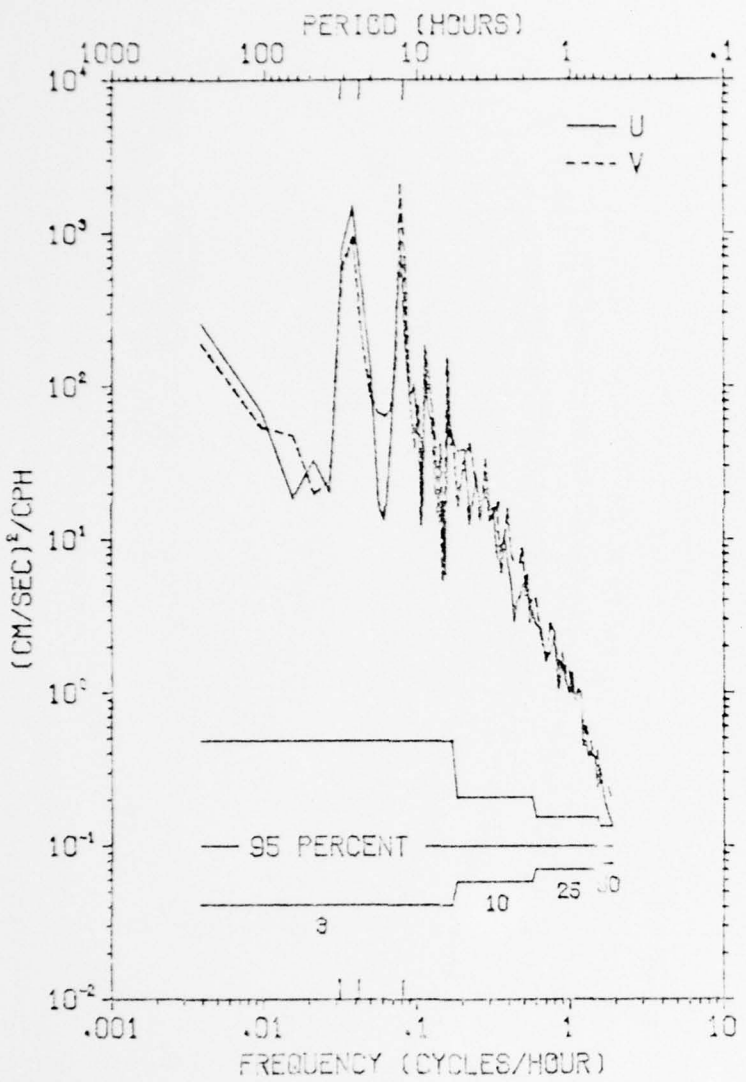
TIME SERIES OF VECTOR AVERAGED CURRENTS AT MOORING DYN., V-0253
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1000 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
AVERAGING INTERVAL = 1.0 HOURS (4 POINTS)

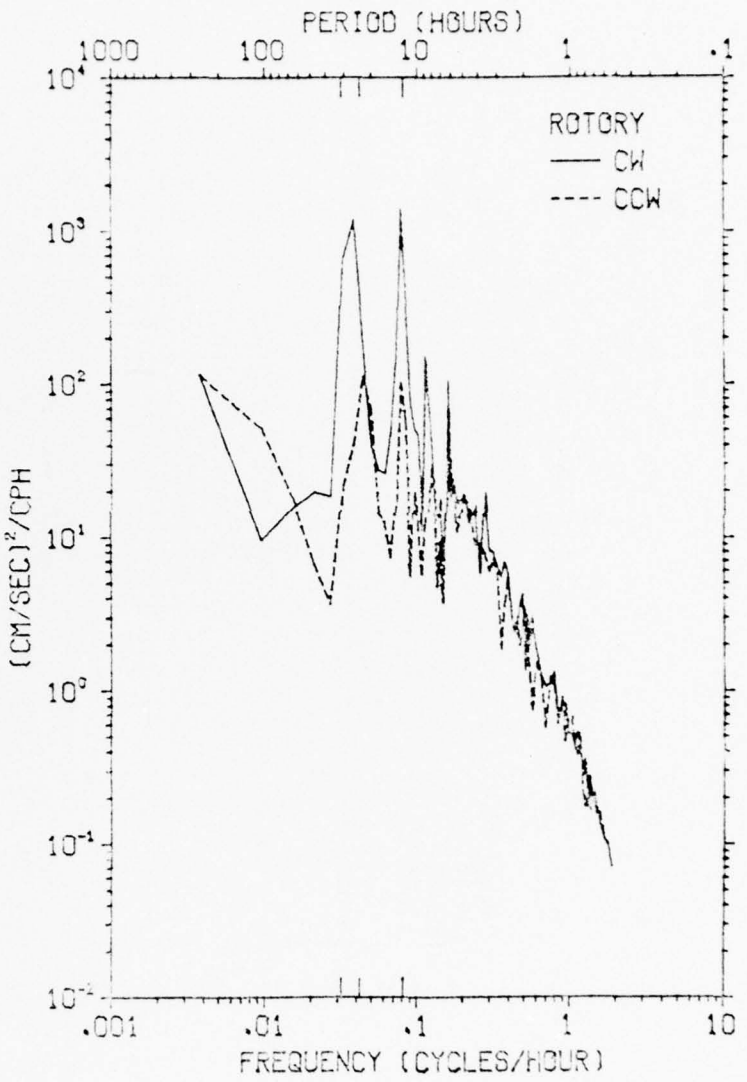


PROGRESSIVE VECTOR DIAGRAM OF CURRENTS AT MOORING DYN., V-0253
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1000 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
* EVERY 1.0 DAYS BEGINNING AT 0000 13 OCT 76

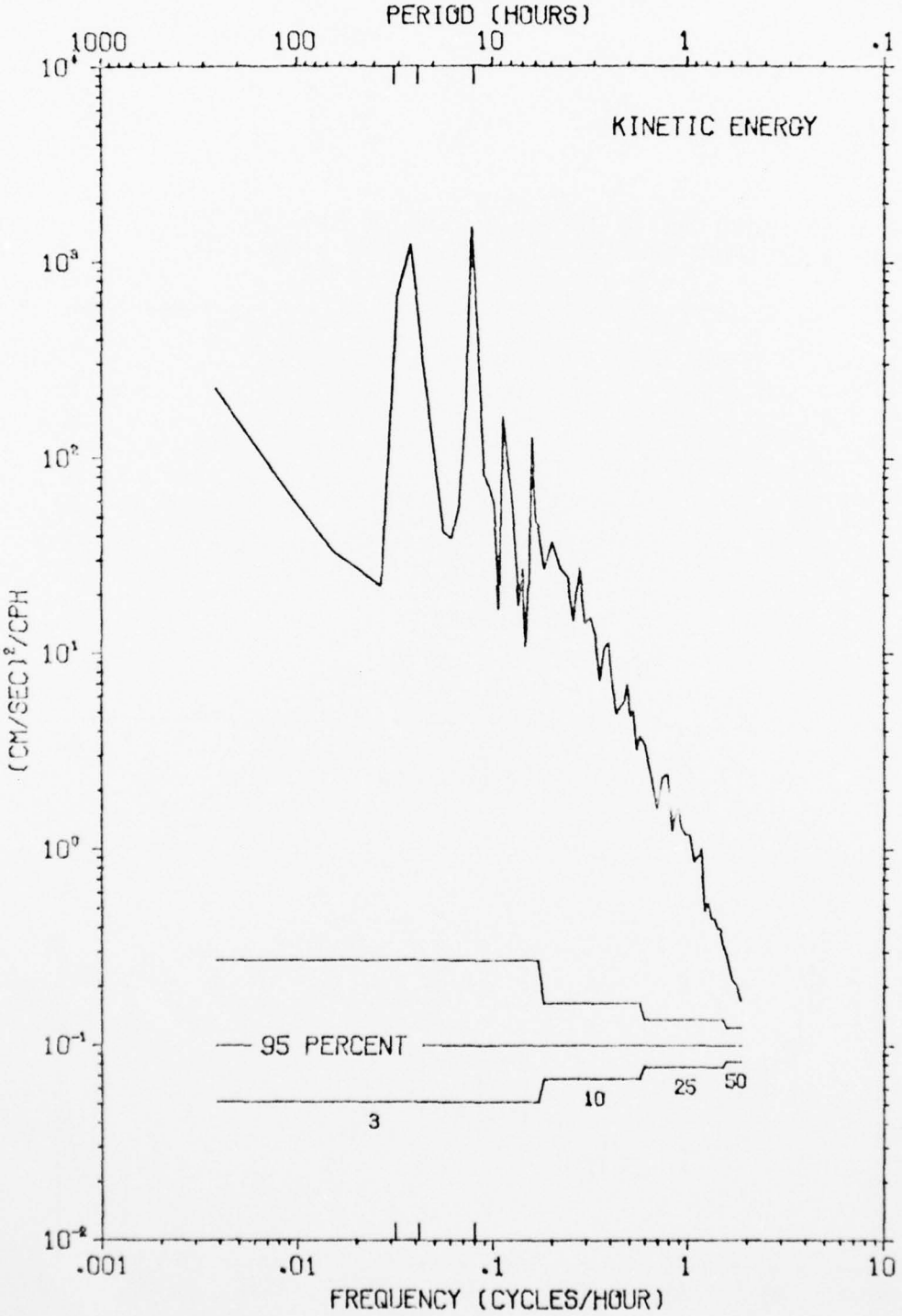


U, V AND ROTORY SPECTRA OF CURRENTS AT MOORING DYN., V-0253
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1000 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, SMOOTHING - DANIELL WINDOW





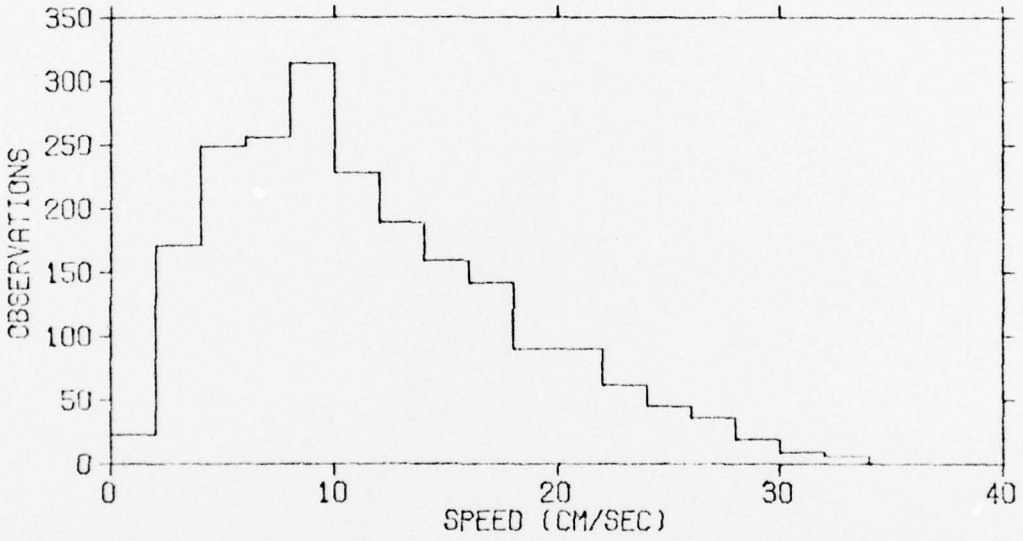
KINETIC ENERGY SPECTRUM OF CURRENTS AT MOORING DYN., V-0253
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1000 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, SMOOTHING - DANIELL WINDOW

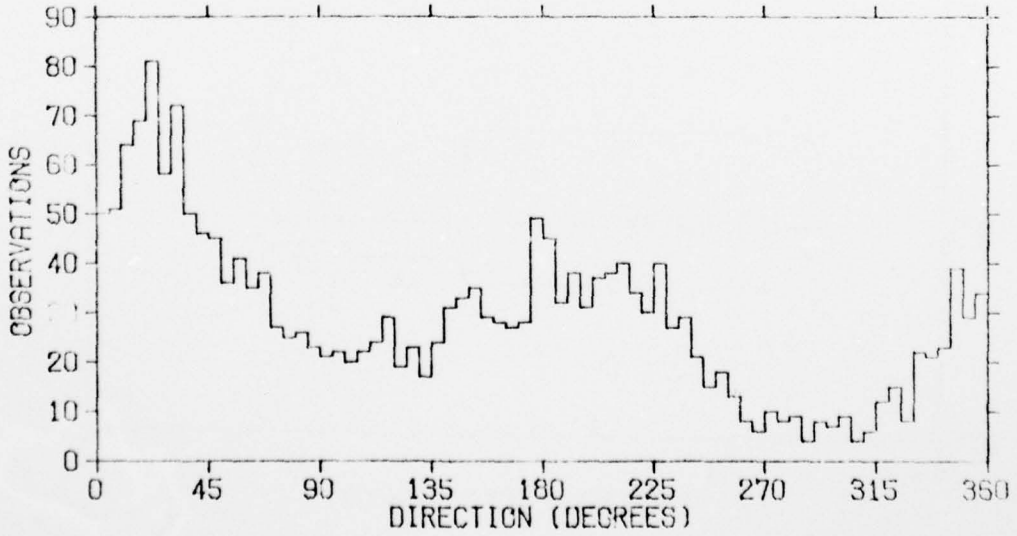


STATISTICS AND HISTOGRAMS OF CURRENTS AT MOORING DYN., V-0230
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1300 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, UNITS = (CM/SEC)

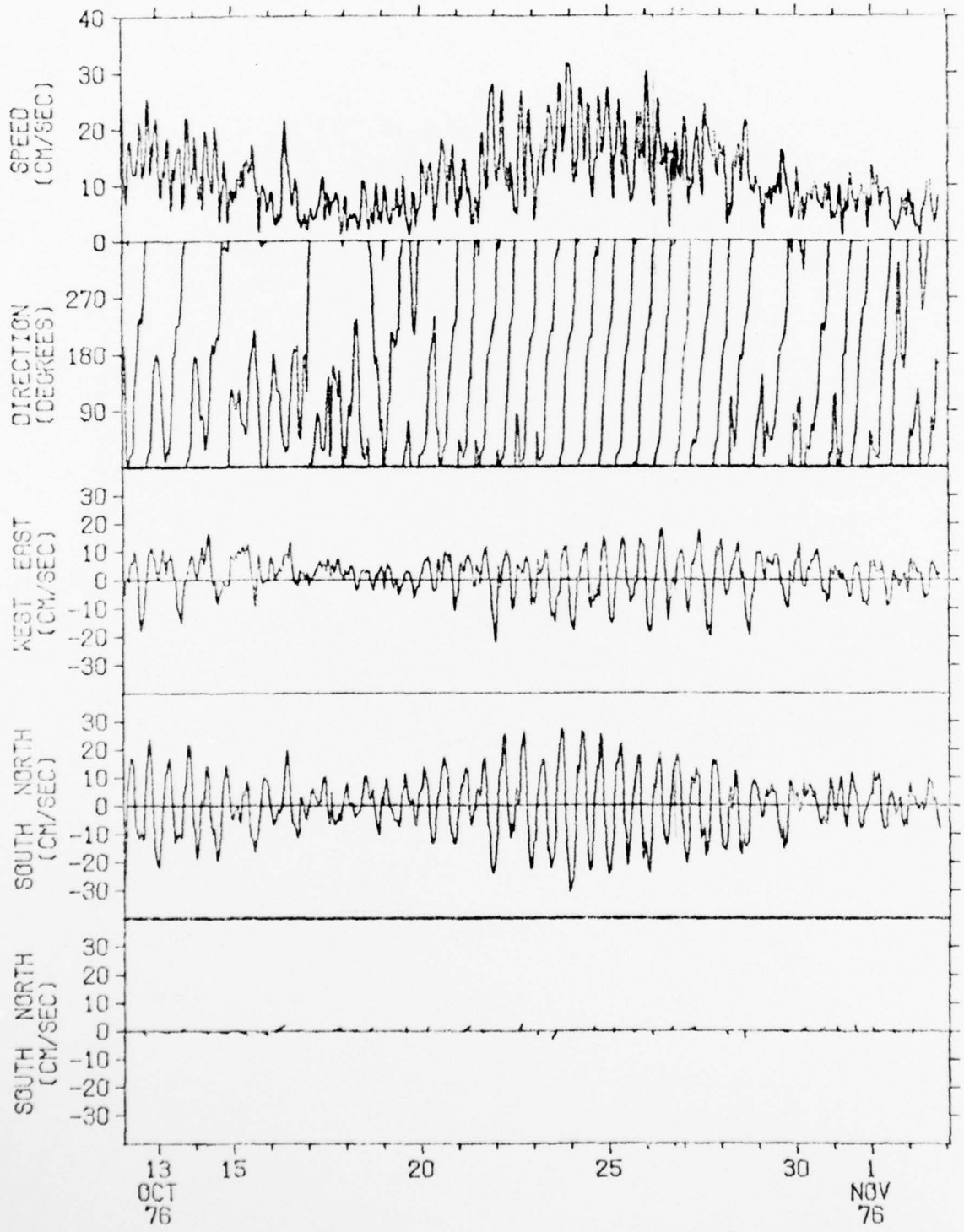
	MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
S	11.65	42.77	6.54	.761	3.023	33.83	.54
U	1.39	52.00	7.21	-.614	3.404	19.88	-23.69
V	.17	124.43	11.15	-.106	2.702	29.19	-32.55

S = SPEED
U = EAST-WEST COMPONENT OF VELOCITY, EAST = POSITIVE U
V = NORTH-SOUTH COMPONENT OF VELOCITY, NORTH = POSITIVE V

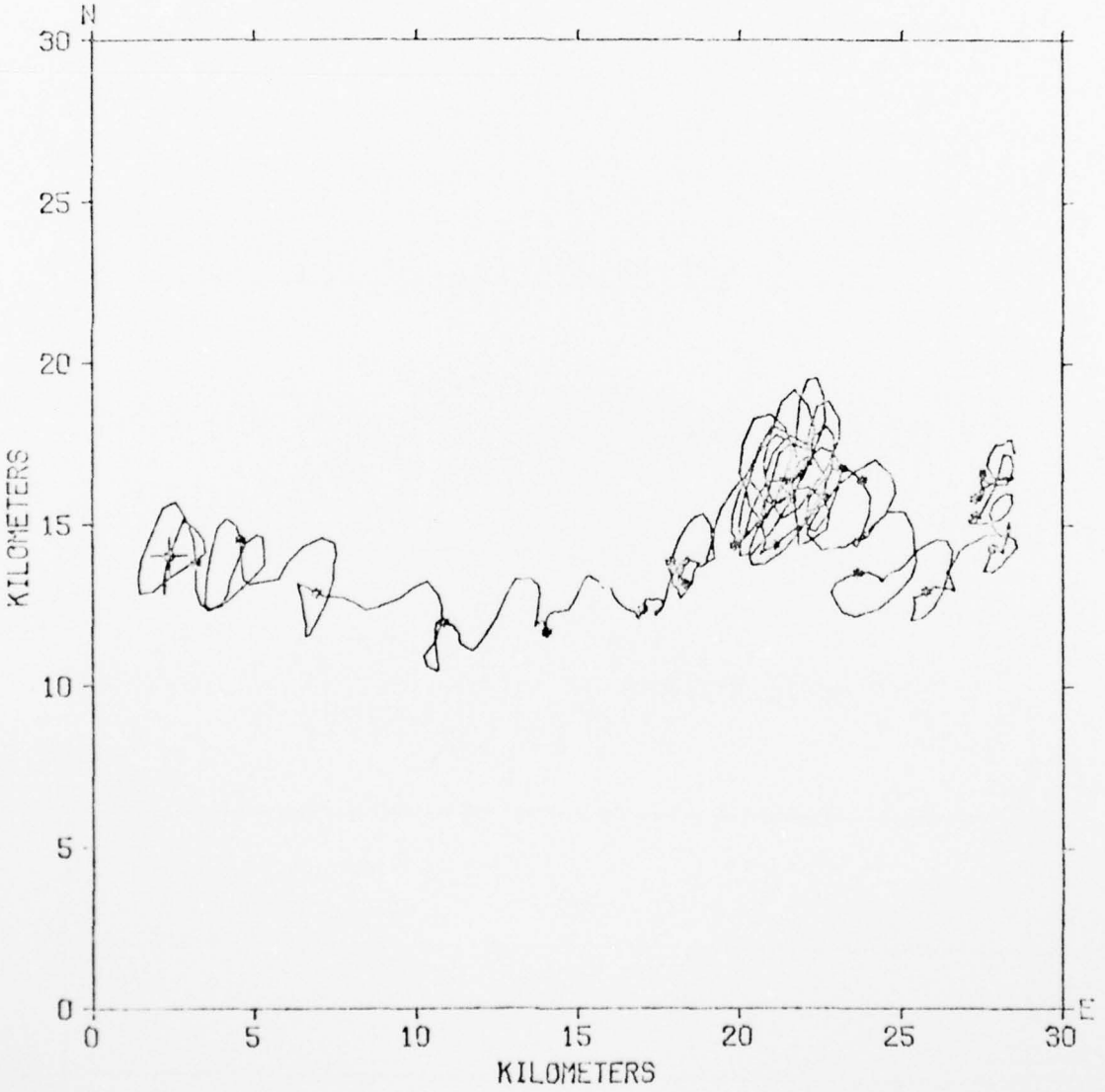




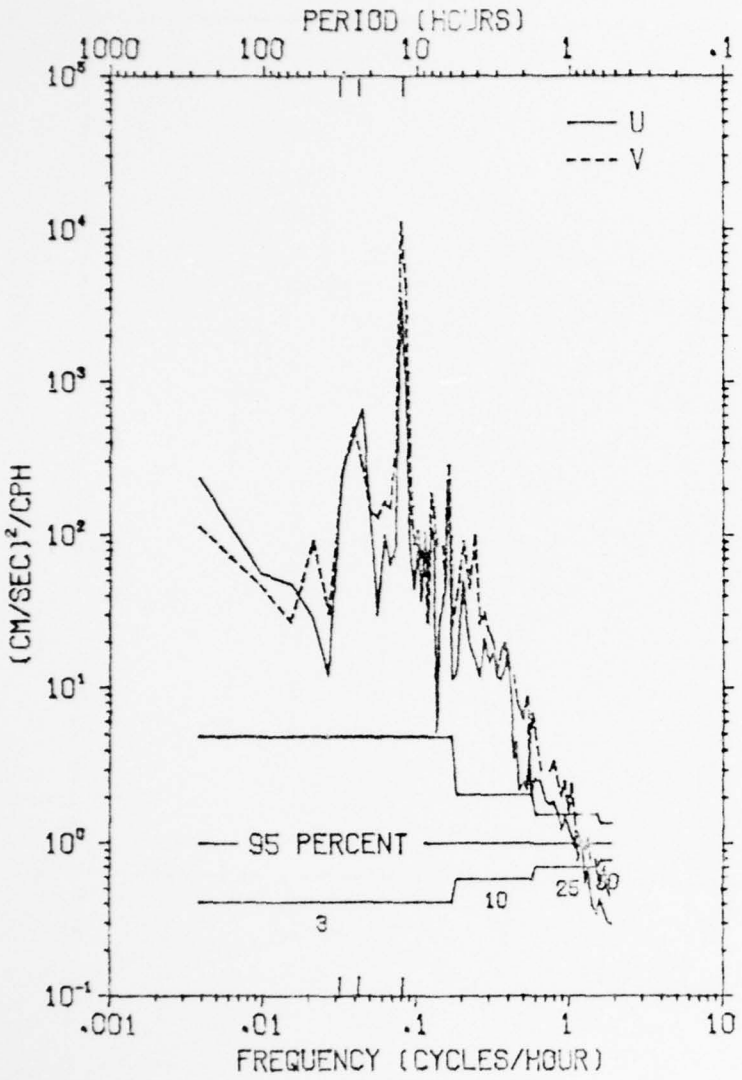
TIME SERIES OF VECTOR AVERAGED CURRENTS AT MOORING DYN., V-0290
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1300 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
AVERAGING INTERVAL = 1.0 HOURS (4 POINTS)

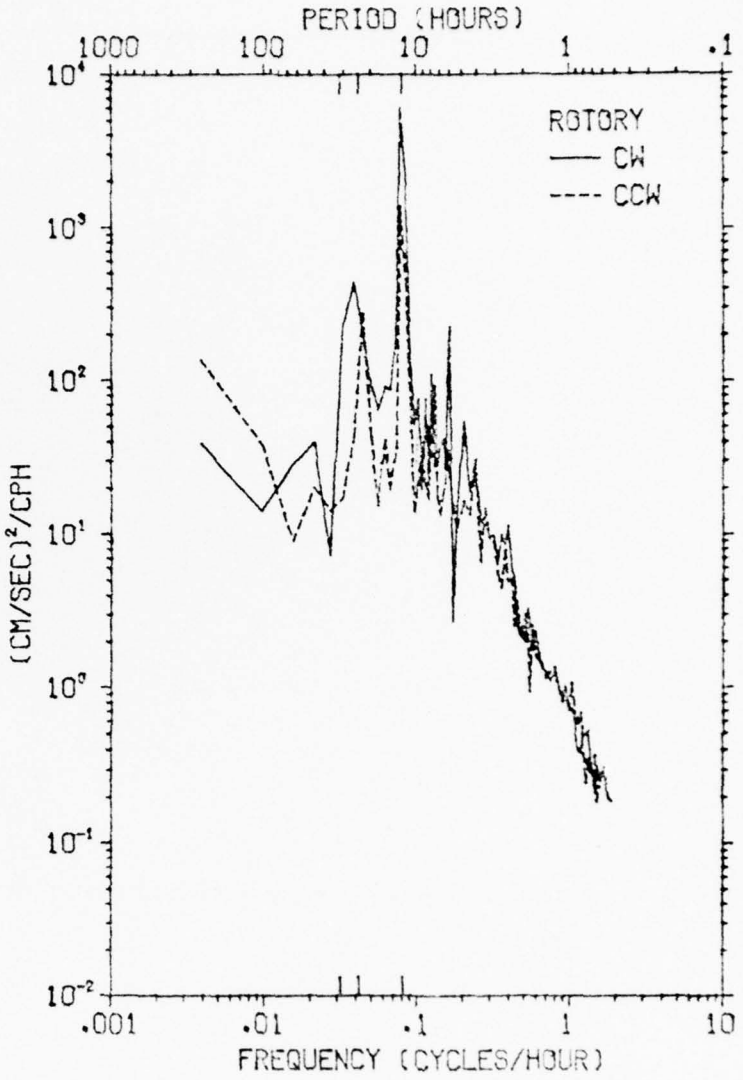


PROGRESSIVE VECTOR DIAGRAM OF CURRENTS AT MOORING DYN., V-0290
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1300 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
* EVERY 1.0 DAYS BEGINNING AT 0000 13 OCT 76

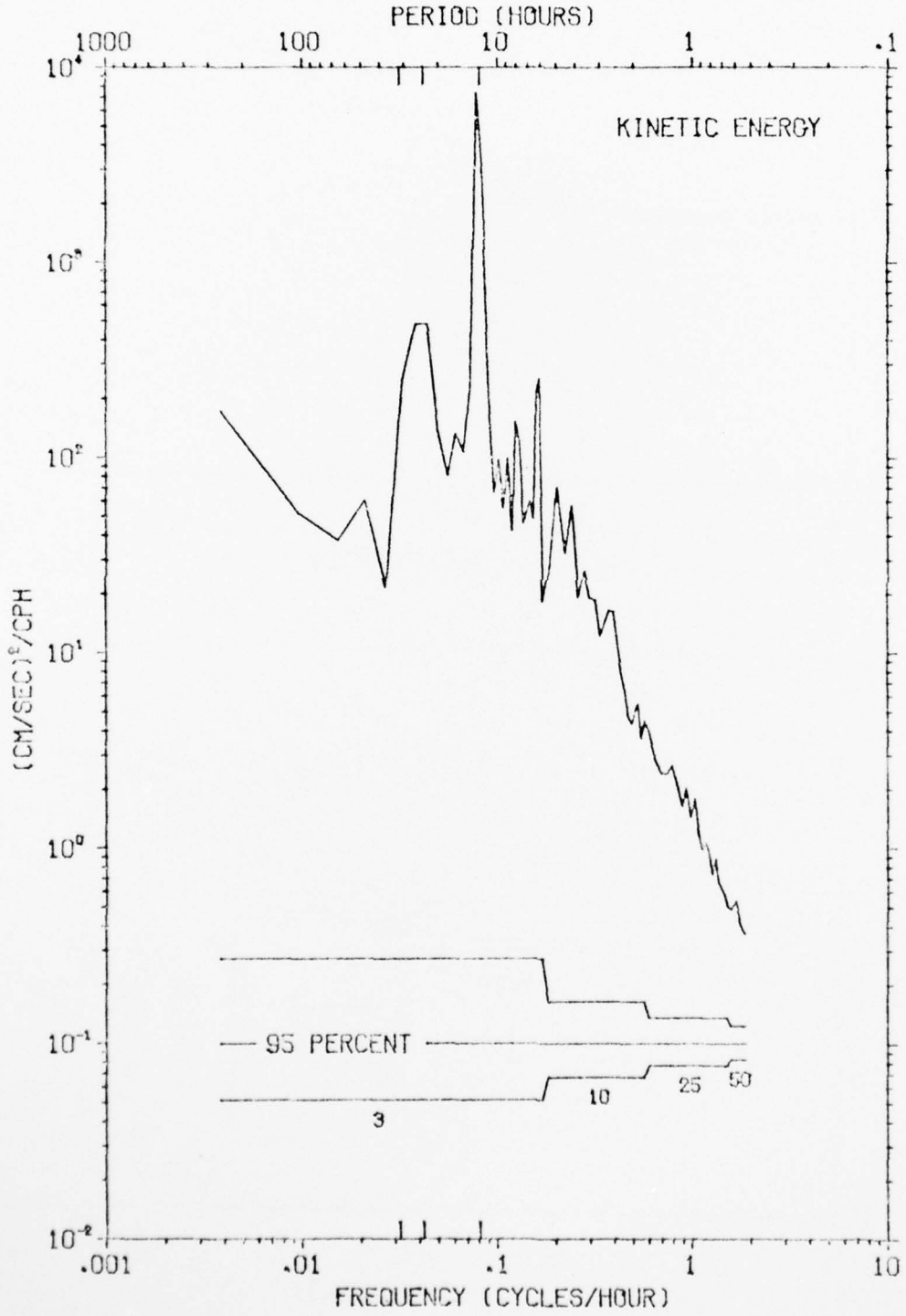


U, V AND ROTORY SPECTRA OF CURRENTS AT MOORING DYN., V-0290
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1300 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, SMOOTHING - DANIELL WINDOW





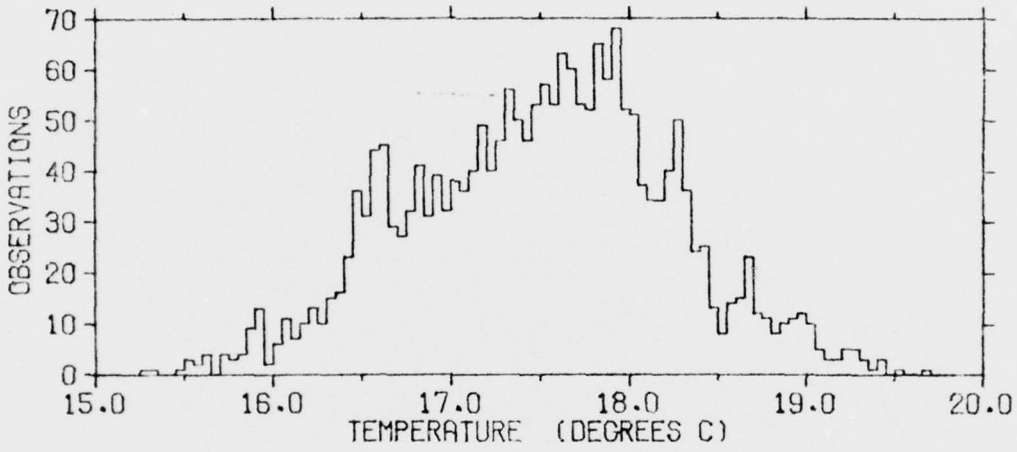
KINETIC ENERGY SPECTRUM OF CURRENTS AT MOORING DYN., V-0290
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1300 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, SMOOTHING - DANIELL WINDOW

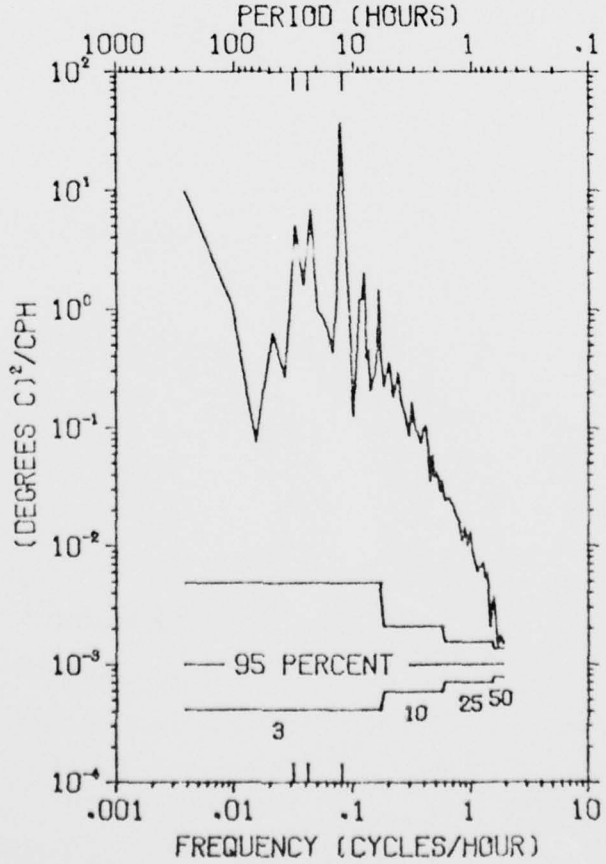


TEMPERATURE

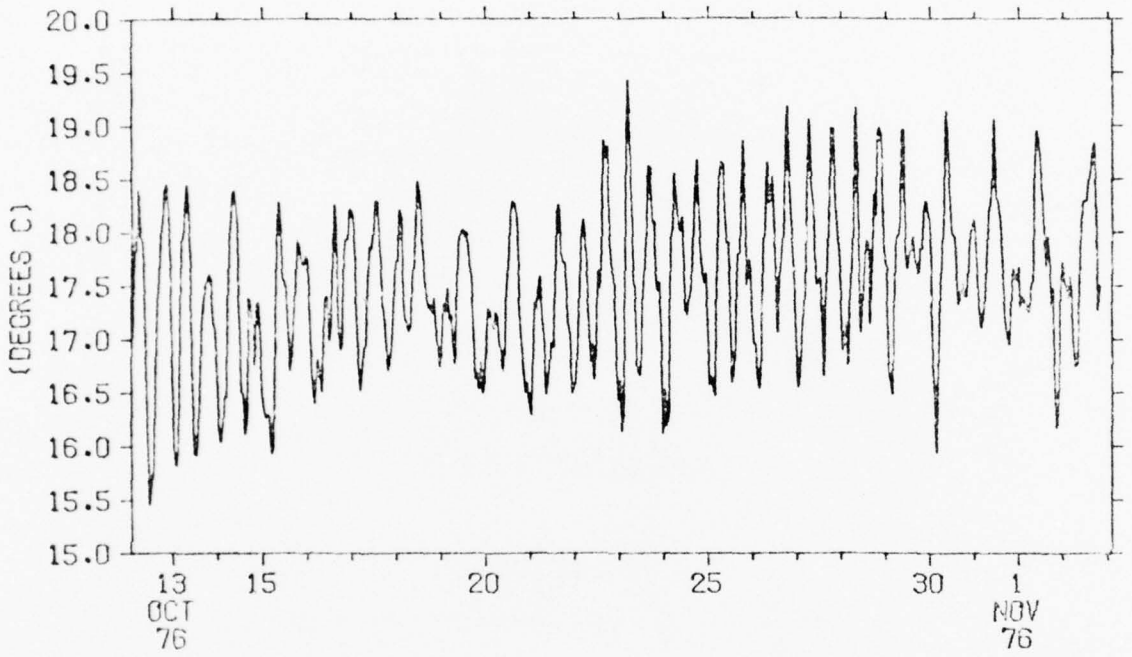
STATISTICS, HISTOGRAM AND SPECTRUM OF TEMPERATURE AT MOORING DYN., V-0295
LOCATION = LAT 22 12.2N, LONG 159 55.8W, DEPTH = 200 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, UNITS = (DEGREES C)

MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
17.50	.540	.74	-.068	2.736	19.70	15.29



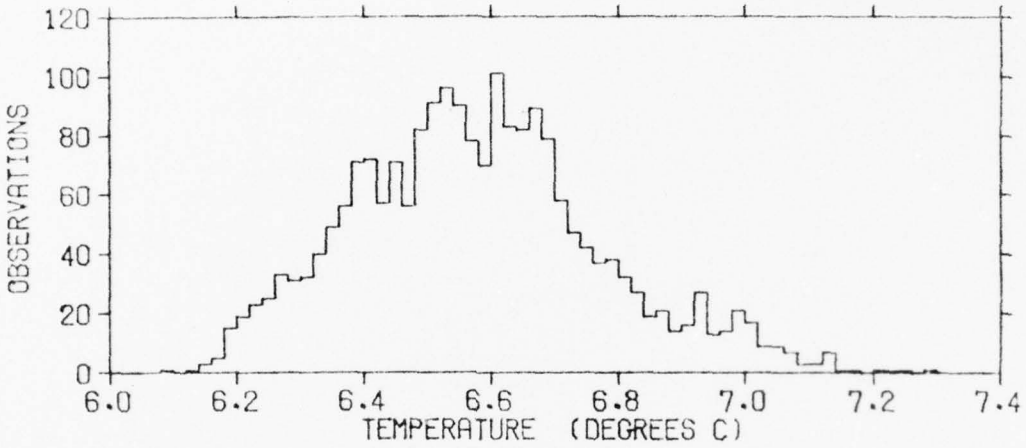


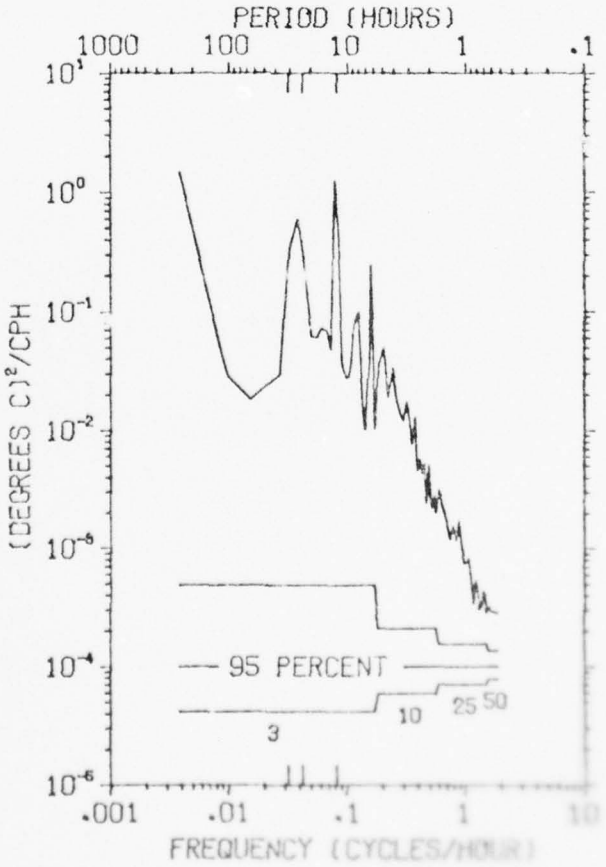
TIME SERIES OF AVERAGED TEMPERATURE AT MOORING DYN., V-0295
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 200 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1900 2 NOV 76 (21.7 DAYS)
AVERAGING INTERVAL = 1.0 HOURS (4 POINTS)



STATISTICS, HISTOGRAM AND SPECTRUM OF TEMPERATURE AT MOORING DYN., V-0293
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 500 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, UNITS = (DEGREES C)

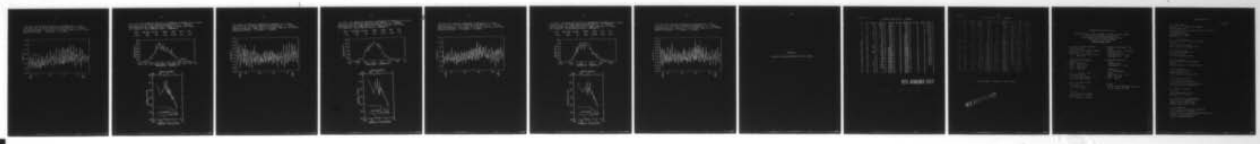
MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
6.58	.039	.20	.392	3.013	7.28	6.09





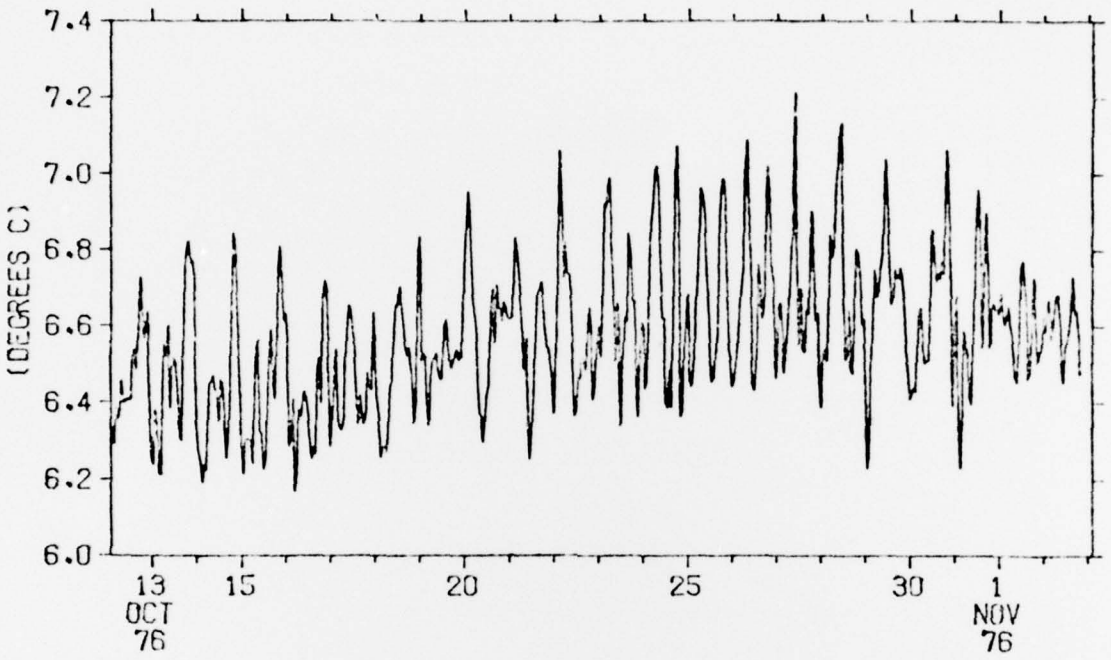
AD-A047 984 WOODS HOLE OCEANOGRAPHIC INSTITUTION MASS F/G 8/3
VALIDATION TESTING OF THE DOCMS INTERMEDIATE MOORING.(U)
SEP 77 R G WALDEN, C W COLLINS, P R CLAY N00014-75-C-1064
UNCLASSIFIED WHOI-77-53 NL

2 OF 2
AD A047984



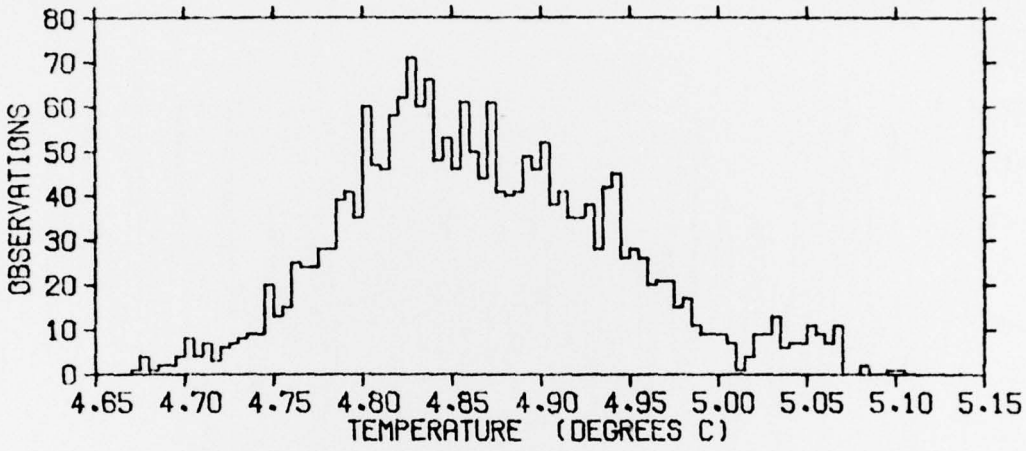
END
DATE FILMED
1 -78
DDC

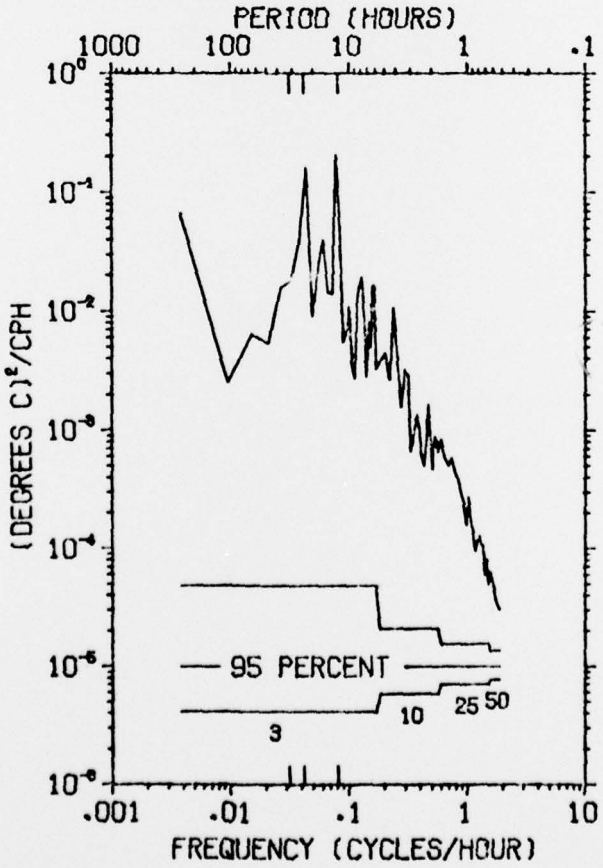
TIME SERIES OF AVERAGED TEMPERATURE AT MOORING DYN., V-0293
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 500 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1900 2 NOV 76 (21.7 DAYS)
AVERAGING INTERVAL = 1.0 HOURS (4 POINTS)



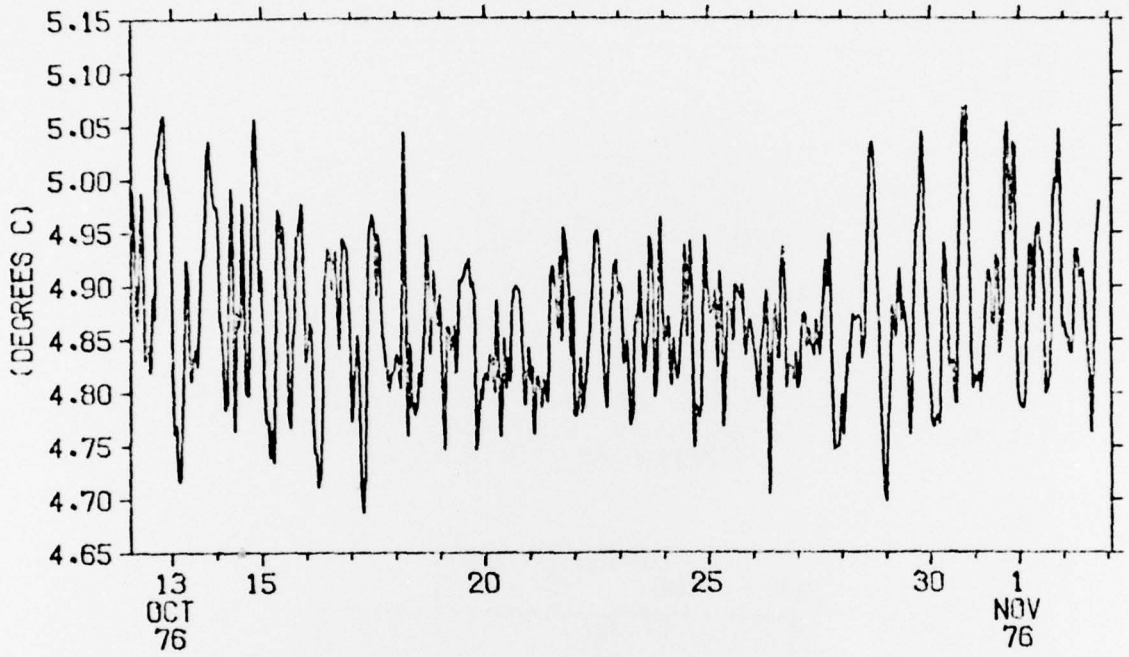
STATISTICS, HISTOGRAM AND SPECTRUM OF TEMPERATURE AT MOORING DYN., V-0264
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 750 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, UNITS = (DEGREES C)

MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
4.87	.006	.08	.357	2.960	5.10	4.67



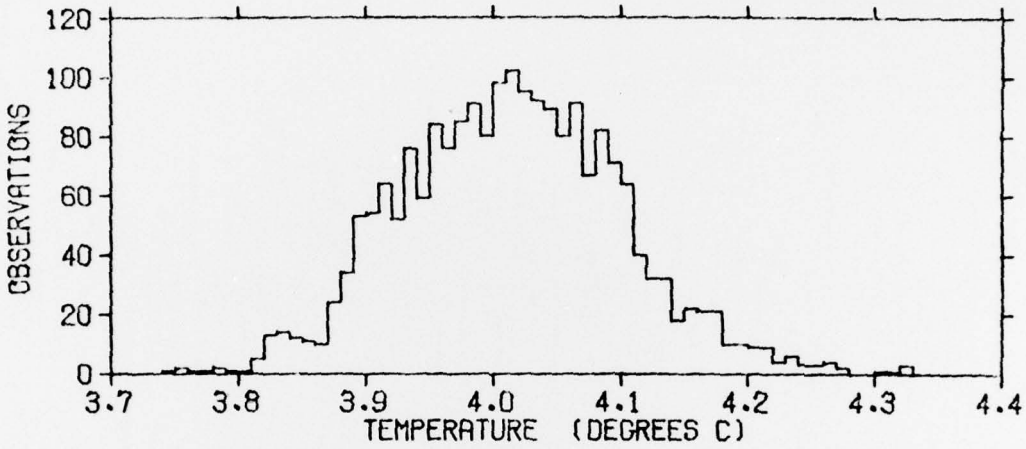


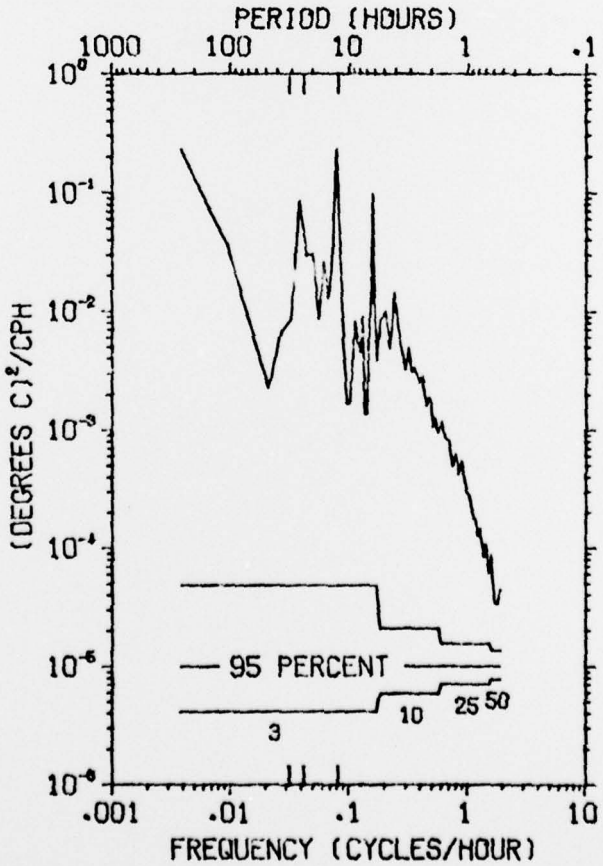
TIME SERIES OF AVERAGED TEMPERATURE AT MOORING DYN., V-0264
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 750 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1900 2 NOV 76 (21.7 DAYS)
AVERAGING INTERVAL = 1.0 HOURS (4 POINTS)



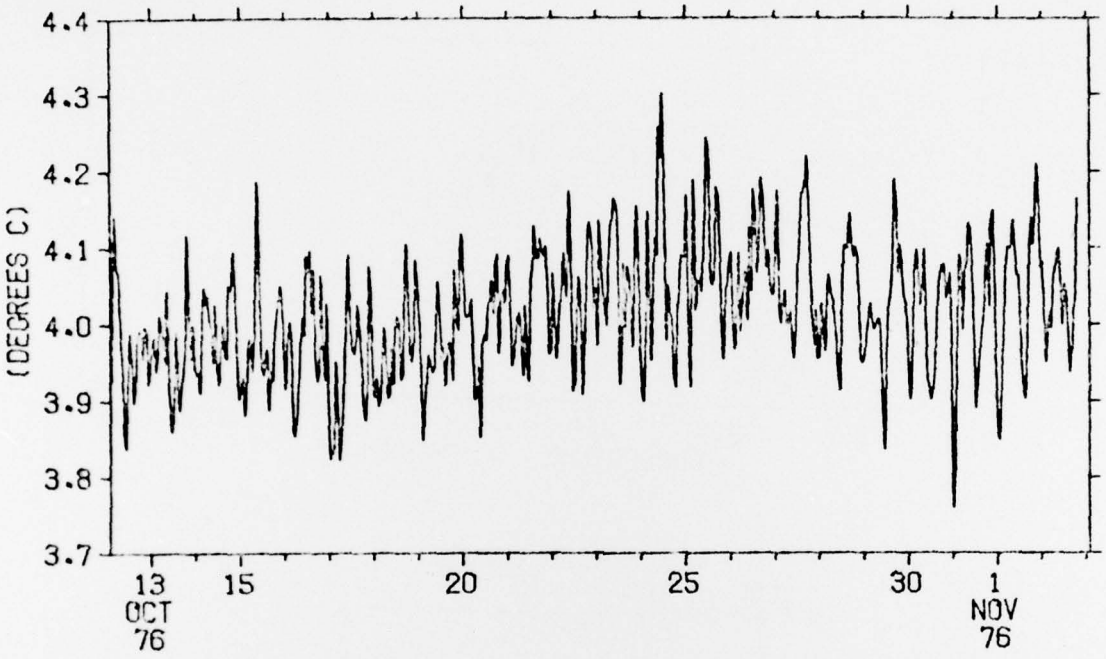
STATISTICS, HISTOGRAM AND SPECTRUM OF TEMPERATURE AT MOORING DYN., V-0253
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1000 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, UNITS = (DEGREES C)

MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
4.01	.007	.09	.181	3.130	4.33	3.74



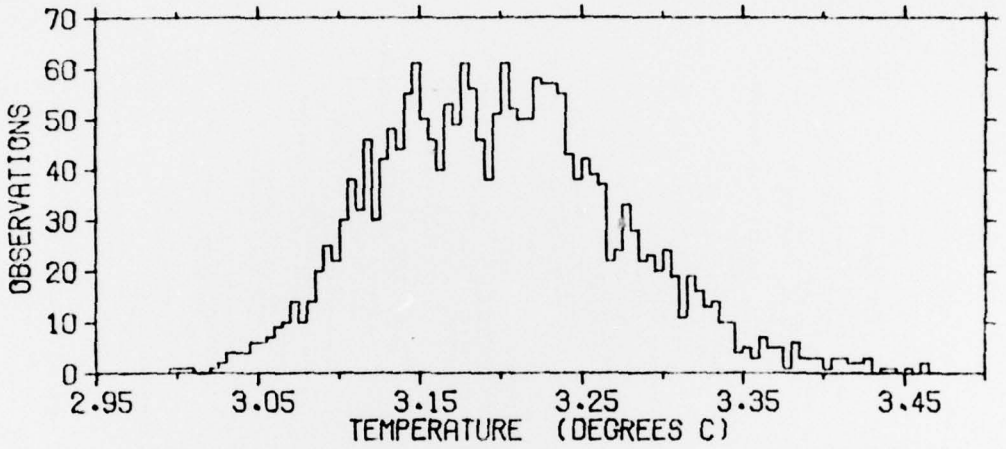


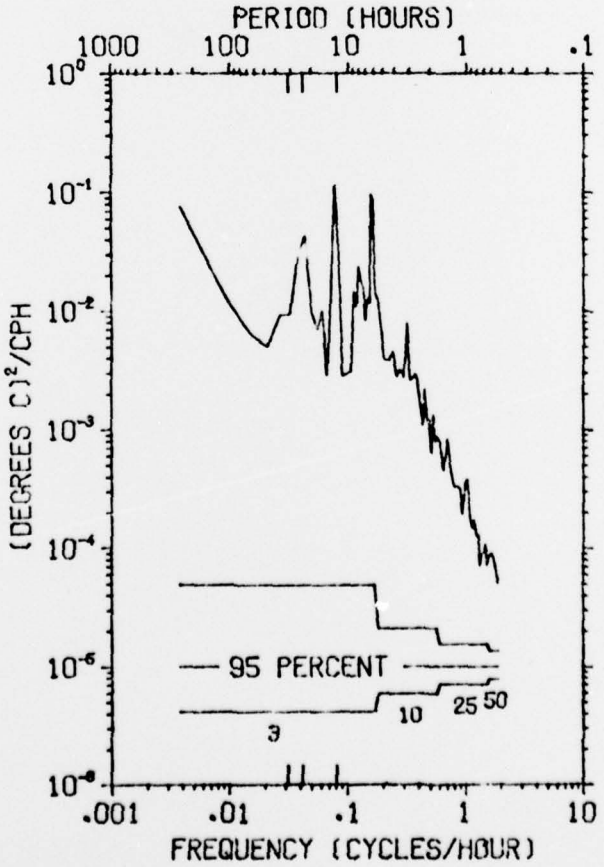
TIME SERIES OF AVERAGED TEMPERATURE AT MOORING DYN., V-0253
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1000 METERS
OBSERVATION PERIOD = 0200 12 OCT '76 TO 1900 2 NOV 76 (21.7 DAYS)
AVERAGING INTERVAL = 1.0 HOURS (4 POINTS)



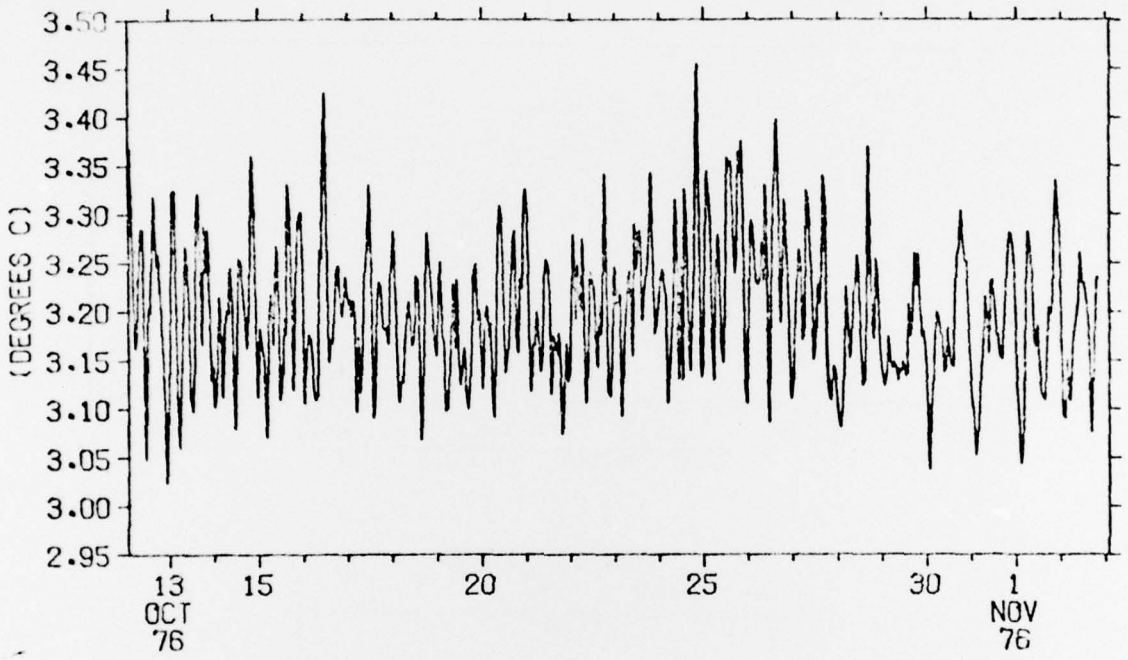
ATISTICS, HISTOGRAM AND SPECTRUM OF TEMPERATURE AT MOORING DYN., V-0290
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1300 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1945 2 NOV 76 (21.7 DAYS)
N = 2088, DT = 15.00 MINUTES, UNITS = (DEGREES C)

MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
3.20	.006	.07	.356	3.058	3.46	3.00





TIME SERIES OF AVERAGED TEMPERATURE AT MOORING DYN., V-0290
LOCATION = LAT 22 12.2N, LONG 159 56.8W, DEPTH = 1300 METERS
OBSERVATION PERIOD = 0200 12 OCT 76 TO 1900 2 NOV 76 (21.7 DAYS)
AVERAGING INTERVAL = 1.0 HOURS (4 POINTS)



APPENDIX 2

Computer Listing and Printout (Initial Design)

DOCMS 8/4/75

MOORING STATISTICS - SUMMARY

COMP	TYPE	LENGTH	WEIGHT	DEPTH	INCLIN	TENSION	EXCUR	DRAG	BACK-UP
1	36	1.1	1050.0	259.8	.0	1047.8	.0	.0	1519.1
2	22	20.0	-102.4	280.0	.0	943.2	.0	.0	1623.6
3	25	1.4	-49.6	281.6	.0	891.4	.0	.0	1675.4
4	22	2.0	-10.2	283.8	.0	879.0	.0	.0	1687.9
5	33	1.1	-53.0	285.0	.0	823.8	.0	.0	1743.1
6	2	63.0	-16.8	348.3	.0	804.9	.0	.0	1762.0
7	40	23.0	1219.0	371.5	.0	2021.7	.0	.0	545.2
8	25	1.4	-49.6	373.1	.0	1969.9	.0	.0	597.0
9	22	2.0	-10.2	375.3	.0	1957.5	.0	.0	609.4
10	37	.4	-18.0	376.0	.0	1937.3	.0	.0	629.6
11	22	2.0	-10.2	378.2	.0	1924.8	.0	.0	642.0
12	33	1.1	-53.0	379.4	.0	1869.7	.0	.0	697.2
13	2	613.7	-163.2	995.5	.0	1704.3	.0	.0	862.7
14	40	6.0	318.0	1001.7	.0	2020.1	.0	.0	546.8
15	34	2.0	-86.0	1003.9	.0	1931.9	.0	.0	635.0
16	2	390.7	-103.9	1396.3	.0	1825.8	.0	.0	741.2
17	37	.4	-18.0	1396.9	.0	1805.6	.0	.0	761.3
18	22	2.0	-10.2	1399.1	.0	1793.2	.0	.0	773.8
19	34	2.0	-86.0	1401.3	.0	1705.0	.0	.0	862.0
20	22	2.0	-10.2	1403.5	.0	1692.5	.0	.0	874.4
21	25	1.4	-49.6	1405.1	.0	1640.7	.0	.0	926.2
22	2	237.8	-63.2	1643.9	.0	1575.3	.0	.0	991.6
23	40	22.0	1166.0	1666.1	.0	2739.1	.0	.0	-172.2
24	35	2.5	-170.0	1668.8	.0	2567.0	.0	.0	.0
25	23	5.0	-45.1	1674.0	.0	2519.7	.0	.0	.0
26	15	20.0	-.9	1697.8	.0	2516.6	.0	.0	.0
27	23	3.0	-27.1	1701.0	.0	2487.3	.0	.0	.0

Current Profile 0 cm/sec Top to Bottom

MOORING STATISTICS - SUMMARY

COMP	TYPE	LENGTH	WEIGHT	DEPTH	INCLIN	TENSION	EXCUR	DRAG	BACK-UP
1	36	1.1	1050.0	299.9	.9	1047.7	312.9	16.8	1519.0
2	22	20.0	-102.4	320.1	2.7	942.9	312.1	44.9	1622.6
3	25	1.4	-49.6	321.7	3.3	891.2	312.0	52.1	1675.4
4	22	2.0	-10.2	323.9	3.6	878.8	311.9	55.2	1687.9
5	33	1.1	-53.0	325.2	4.2	822.8	311.8	60.5	1743.0
6	2	63.0	-16.8	388.2	5.7	804.9	306.2	80.3	1762.0
7	40	23.0	1219.0	411.4	4.8	2017.8	304.2	170.2	545.2
8	25	1.4	-49.6	413.0	5.2	1966.3	304.0	177.4	597.0
9	22	2.0	-10.2	415.2	5.3	1953.9	303.8	180.4	609.4
10	37	.4	-18.0	415.8	5.4	1933.8	303.8	182.2	629.6
11	22	2.0	-10.2	417.9	5.5	1921.4	303.6	185.3	642.0
12	33	1.1	-53.0	419.2	5.8	1866.6	303.4	190.6	697.2
13	2	613.7	-163.2	1026.9	12.7	1703.4	204.4	378.6	862.6
14	40	6.0	318.0	1033.0	11.4	2013.4	203.2	401.8	546.8
15	34	2.0	-86.0	1035.2	12.3	1928.4	202.7	414.3	635.0
16	2	390.7	-103.9	1415.0	16.6	1825.7	104.6	529.5	741.1
17	37	.4	-18.0	1415.5	16.9	1806.5	104.4	531.2	761.3
18	22	2.0	-10.2	1417.7	17.1	1794.6	103.7	534.0	773.8
19	34	2.0	-86.0	1419.7	18.3	1713.5	103.0	545.7	862.0
20	22	2.0	-10.2	1421.8	18.6	1701.7	102.3	548.5	874.4
21	25	1.4	-49.6	1423.3	19.4	1654.6	101.8	554.9	926.2
22	2	237.8	-63.3	1646.3	22.5	1593.5	16.4	620.2	991.6
23	40	22.0	1166.0	1667.6	14.7	2709.2	10.2	700.1	-172.2
24	35	2.5	-170.0	1670.2	16.3	2548.1	9.4	726.0	.0
25	23	5.0	-45.1	1675.2	16.8	2502.8	7.9	734.6	.0
26	15	20.0	-.9	1697.9	17.1	2499.8	1.0	747.0	.0
27	23	3.0	-27.1	1701.0	17.4	2471.9	.0	752.3	.0

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A Deep Ocean Current Measurement System (DOCMS) was developed for the U. S. Naval Oceanographic Office under a contract with the U. S. Naval Facilities Engineering Command. A test of this mooring was made at the Pacific Missile Range Barking Sands Facility, Hawaii, to validate the design predictions. The motions of the mooring, both predicted and measured are tabulated and show good agreement. Current measurements were made from current meters on the DOCMS and on a nearby intermediate mooring. Current measurements from the surface to 500 meters were also obtained using an acoustic dropsonde. Acoustic pingers on the mooring were tracked in X, Y and Z coordinates by the range to provide data on the mooring motions and shape.

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2. Current Measurements
3. Mooring Motion

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